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The Institute of Vitreous Enamellers
The National Ironfounding Employers' Federation
The Welsh Engineers' and Founders' Association
and
The Foundry Trades' Equipment and Supplies Association

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The Glasgow Conference

It is almost eleven years since, under the presidency of Mr. John Cameron, Scotland had the privilege of entertaining the members of the Institute of British Foundrymen. On that occasion, the light-castings industry was featured, and visits were made to some of the foundries in the Falkirk area. At the forthcoming conference, it is the engineering side which is opening its foundries for inspection. Several of the works have undertaken large-scale alterations in recent years. Singers have an exceptionally well-equipped core-making department; Babcock & Wilcox have recently installed a mechanised continuous-casting plant; Glenfield & Kennedy is also mechanised, especially in respect to sand control; Harland & Wolff's Govan Foundry—known locally as the Crystal Palace—is probably the largest foundry building in Great Britain, and is of recent construction; whilst John Lang & Sons, Limited, ranks as one of the foremost machine tool makers in Scotland.

Most of the Papers and reports have now been through our hands, and they constitute an exceptionally fine blend of practical and theoretical data. All phases of foundry practice are touched upon, and it will be found that non-ferrous work will figure more prominently than the printed programme indicates, as the official French Exchange Paper uses light alloys with the object of elucidating mathematically the underlying principles of the running properties of metals.

For the social side, much depends on the weather, but Scotland has a reputation of providing abundant sunshine when it entertains the Institute. Scotland in June can be, and usually is, particularly delightful. The Scottish Committee have been at an immense amount of trouble to provide a well-balanced programme, and it is now for the directorates of all the foundry concerns to see that they are adequately represented. The main benefits are only to be derived from personal participation. Personal contacts will provide information of greater value than can ever be obtained from the most carefully-prepared printed reports. Trade is good, and this should be reflected in a record meeting. To make the excuse that time cannot be spared for attendance is reminiscent of the perpetually untidy (and often unremunerative) foundry. In the latter case, two excuses are invariably given. When trade is good, no time is available for cleaning up the plant, and, when times are slack, the cost cannot be supported. We appeal to every executive, either personally to participate in the forthcoming conference or to accord permission for his assistants to make the trip. It will probably be another decade before Scotland again assumes the *rôle* of host.

Metal Goods Production, 1930-1933

A report was published recently by the Stationery Office giving the results of an inquiry by the Board of Trade with the object of comparing British industrial activity in the years 1930 and 1933, so as to show up any effects of the tariff changes under the Import Duties Act of 1932. The 1930 year was that of the Census of Production, and the 1933 inquiry was carried out on the same lines. The results, published in two reports, cover the iron and steel and engineering trades. Many trades were not included at all and others only when they referred to establishments employing more than ten, but the total inquiry covered 62 per cent. of the output and 69 per cent. of the persons employed in factory industries.

The iron and steel trades as a whole show a gross output value for 1933 of just over two hundred millions sterling, compared with 36 millions more for 1930, but if the difference in price levels is accounted for the disparity is reduced to 15 millions.

Dealing only in round figures, the value of pig-iron and ferro alloys made in 1933 was twelve millions, or fourteen millions on the revalued basis on 1930 prices, compared with twenty-two millions in 1930. For iron and steel castings the value of material produced in 1933 was twenty-seven millions, or over twenty-eight millions at 1930 prices, compared with twenty-nine millions for 1930. Curiously, somewhat similar figures hold for hardware, hollow-ware, metallic furniture and sheet metal goods, otherwise unclassified. The engineering trades as a whole, excluding motor vehicles, showed a gross output for 1933 of 206 millions, compared with 270 millions in 1930, which shows even more the impact of the depression than the iron and steel industry, whose prices, however, had not so far to fall. Mechanical engineering suffered more than electrical engineering.

In the non-ferrous trades the gross output value increased from 98 millions in 1930 to 138 millions in 1933, but after deducting cost of materials used the net figure showed a decline from 23 to 22 millions, the values first mentioned being affected by the price of gold. Actually, there was little change in the values in copper and brass goods in 1933 and 1930, based in each case on 1930 values, while in the case of other common non-ferrous metals, including aluminium, there was also little change. These figures will serve to check common experience in various sections of the trade as to business between these two dates, since when there has, of course, been a welcome change for the better.

Grinding Wheels in the Foundry

DISCUSSION IN BRADFORD

The final meeting of the 1935-36 session of the West Riding of Yorkshire Branch of the Institute of British Foundrymen was held in the Bradford Technical College. The chair was occupied by Mr. Joseph Hepworth, M.P., who had been elected Branch-President at the previous meeting.

The speaker was MR. S. L. IRELAND, a member of the Birmingham Branch, who gave a lecture, illustrated with lantern slides, on "Grinding Wheel Practice in the Foundry." Mr. Ireland's remarks were largely descriptive of the production of grinding wheels, and he went on to refer to the wide range to meet modern needs, and made particular reference to grinding in the foundry. The more serious side of his lecture was enlivened by occasional witticisms of his own, and his pictures were equally enlivened by an occasional humorous sketch thrown on the screen.

Inviting subsequent questions or discussion, the CHAIRMAN (Mr. Hepworth) said the Branch was bringing the session to a close in a particularly happy atmosphere, for they had listened to a lecture of deep interest, yet at the same time not without its lighter touches.

Rôle of High-Speed Grinders

In answer to MR. H. FORREST, the LECTURER said the greatest advantage of the high-speed wheel was usually found in the steel and malleable iron trade. There was possibly an advantage in fettling cast iron, but not so pronounced as in fettling steel. The extra power and necessity for steadier machines had to be taken into consideration.

MR. F. K. NEATH (Past-President of the Branch) inquired whether Mr. Ireland had any figure to suggest in regard to the weight or time factor in respect of different metals.

MR. IRELAND replied that each job had to be taken on its own conditions. In malleable and steel castings the high-speed wheel was definitely of advantage, but to lay down any hard and fast rule as to weight or time factor was impossible.

Large and Small Wheels

MR. HEPWORTH asked what ratio of efficiency, if any, was there in precision grinding, on the article being ground, as between the large or small wheel?

MR. IRELAND said he would prefer a big wheel.

MR. HEPWORTH said several questions he had contemplated asking had been answered in the course of the lecture. The method of testing a wheel for cracks and soundness was one which had been partly answered. He would be interested if the lecturer could say what type of bond he would recommend in actual workshop practice.

MR. IRELAND said that the method of testing was to run the wheel at a substantially higher speed than that of normal practice. A wheel destined to run at 5,000 surface feet would be tested at, say, 8,000 ft.; it would soon reveal the existence of any defect. The best bond for workshop practice depended entirely on the class of work, and for fettling in the general foundry nothing was better than the resinoid bonded wheels. He did not, however, recommend this for precision work.

Efficient Grinding Speeds

MR. F. K. NEATH asked what ratio existed in extent of wearing down a wheel in general foundry fettling, where the wheel was usually one of a multi-purpose character rather than for special uses.

MR. IRELAND advised them to keep the speed of the vitrified wheel at 5,000 surface feet. With a machine having a variable speed one could be sure that the fettler would run it at its fastest if allowed to please himself. The high-speed wheel should be kept as near as possible to 9,000 surface feet.

In reply to a question by MR. H. A. MCCOLL, MR. IRELAND said that, special circumstances excepted, he would generally recommend the large wheel, if only on grounds of price. It cost less to have a large wheel lasting longer than to make frequent renewals of small wheels. There was sometimes the arc of contact to be considered.

Vote of Thanks

The PRESIDENT moved a hearty vote of thanks to Mr. Ireland for his visit and lecture.

MR. R. D. WELFORD (Past-President of the Branch), seconding, remarked that one sometimes felt the grinder could spend a good deal more time at the wheel than he did.

Replying to the vote of thanks, MR. IRELAND conveyed the greetings of Birmingham Branch of the Institute to the West Yorkshire members. He hoped the talk and illustrations had been interesting, and suggested the Branch might do worse than arrange to visit the works he had described.

The Institute of Vitreous Enamellers

SECOND SCOTTISH CONFERENCE

The Second Scottish Conference of The Institute of Vitreous Enamellers is to be held in Glasgow on May 30 and 31 and June 1, 1936. Every effort has been made to make this conference valuable, both technically and socially, and all friends of members and prospective members and their ladies will be warmly welcomed.

Lectures are being given by H. T. Angus, Ph.D., M.Sc., on "Cast Iron for Vitreous Enamelling," and J. G. Holmes and A. Linley on "Heat-resisting Steels and their Application to Pettits and Pettit Design." The detailed programme is as follows:—

SATURDAY, May 30, 1936, at Central Hotel, Glasgow.

3.0 p.m.—Technical meeting in Ailsa Room, Central Hotel, Glasgow.

5.0 p.m.—Afternoon tea.

5.45 p.m.—Discussion on Papers.

8.0 p.m.—Supper at Central Hotel.

SUNDAY, May 31.—Sail to Corrie (Arran) via Kyles of Bute.

10.30 a.m.—Assemble at Central Hotel.

11.0 a.m.—Leave Glasgow for Gourock. (Lunch and tea on steamer.) Visitors wishing to sail up the Clyde on the return journey may do so on payment of extra fare. Change steamers at Gourock.

6.30 p.m.—Arrive Glasgow.

MONDAY, June 1.

12.0 noon.—Luncheon. Members to make own arrangements.

1.0 p.m.—Assemble at Central Hotel.

1.15 p.m.—Leave Central Hotel by motor-coach for visit to works of Carron Company, Falkirk. Members wishing to use own cars for this visit please notify Conference Secretary.

Arrangements for accommodation have been made at the Central Hotel, Glasgow, where there are inclusive charges for bed and breakfast as follow:—Single room, 12s. 6d.; double room, 25s. Application must be made direct to the hotel, mentioning the conference.

Further details can be had on application to Mr. J. G. Roberts, Shanks & Company, Limited, Tubal Works, Barrhead, near Glasgow.

Students' Corner

SECOND SERIES

Cupola Practice—*(continued)*

The following is the analysis of a suitable cupola flux:—Lime, 50 to 53 per cent.; carbon dioxide, 42 to 45 per cent.; silica, under 1 per cent.; and very small percentages of hydrogen, phosphoric acid and ferrous oxide.

The silica sand and dirt adhering to the iron in the charge and the ash from the coke are acid. Accordingly, a material which is basic must be added, which, in the fusion zone, will unite with the acid materials to form a fusible free flowing slag. An acid is the oxide of a non-metal and a base is the oxide of a metal. Both have a strong chemical affinity for each other, depending upon the compound, and combine in definite proportions. The oxides of some metals are not basic. When limestone (calcium carbonate) is charged with the coke and metal into the cupola, on reaching the hot zone, quantities of carbonic acid gas are evolved, causing much deflagration and resulting in the formation of lime. This remains as such until the temperature of about 1,000 deg. C. is reached, when it combines with the silica and other foreign acid matter to form the slag.

Both fluorspar and limestone are lime-producing. Fluorspar contains about 10 per cent. more of lime-producing calcium than limestone, and while 44 per cent. of limestone is volatilised and passes up the stack of the cupola, the whole of the fluorspar is utilised, as it does not decompose until the fusion zone is reached. If the fluxing material is limestone, it is soon decomposed by the heating action of the ascending gases, causing the lime to descend and combine with the silica to form silicate of lime. The chemical reactions or combinations are as follow: (1) Limestone is reduced to lime; (2) lime combines with silica, forming lime silicate; (3) iron oxide combines with silica, forming ferrous silicate; (4) lime combines with iron sulphide, forming calcium sulphide and ferrous oxide.

Q. 10.—*Is the appearance of the slag an indication that melting conditions are favourable, or otherwise?*

A.—With cupolas that are running daily and producing one class of iron, the fluidity or sluggishness, colour and general appearance of the slag should be some indication of the conditions. Cupola slags vary in colour from grey to black, and may be classed as silicates or aluminates, and are the results of combination of silica, alumina, lime, iron, etc. The condition of the slag is affected by the coke, blast, quality and quantity of the flux, but if these are favourable, a medium colour, free-flowing slag indicates a sufficiency of limestone and a desirable absence of excess ferrous oxide; a viscous, dull black slag indicates a scouring condition, and will be found to be high in iron oxide.

(To be continued.)

Metallurgy of Crucible Steel Manufacture

To elucidate the nature of the metallurgical reactions taking place in the manufacture of crucible steel, O. MEYER, W. EILENDER and A. WALZ have carried out a series of experiments to determine the behaviour of carbon, silicon, manganese, oxygen and nitrogen in these reactions. This work, which is described in the "Archiv für das Eisenhüttenwesen," showed that the boiling of the bath, which has a direct bearing on the quality of the steel produced, is due primarily to a reaction between the crucible carbon and the material of the crucible, and that a reduction of the silicon from the slag is negligible and need not enter consideration. It was also noted that with normal melts interaction between bath, crucible wall and slag always resulted in a slag of approximately constant composition.

Manufacture of Locomotive Castings*

By H. LOWE

This Paper mainly refers to the production of locomotive castings at the St. Rollox workshops of the L.M.S. Railway Company. There is a definite necessity for the chemical analysis of pig-iron, and the only way in which good results can be obtained is to analyse all the materials and carefully control the proportion of the charges that go into the cupola. To ensure correct results, check analyses are made of samples of the iron as received.

The method is to take three or four pigs from different parts of the truck, break them and take drillings from the centre, care being taken that no sand from the outside becomes mixed with the drillings. They are then put into envelopes and carefully marked with the number of the truck and such other information as will serve to identify this particular lot of iron, and then submitted to the chemist. If it is found that the material is not to specification, a full report is sent to the makers, and the wagon marked "rejected." The same procedure is adopted with all other materials such as coke, lime, shell, and moulding sands.

Furnace Charges

The furnace charges are put on a board on the charging platform, which shows the amount of charges and the different mixtures for the day. At the tapping spout on the wall there is an indicator showing the different classes of metal that are being tapped. This is a guide to the metal carriers, who then know to which section of the shop the metal should be taken. There are four different mixtures melted in the furnaces each day, for castings such as brake blocks, signal castings, cylinders, engine details and axleboxes.

FIG. 2.—CORE RACKS.

Cylinders, cylinder covers, piston heads, piston rings, piston valve liners, slide bars, motion plates and all high-pressure castings are manufactured by the dry sand process.

Dry sand moulding is essentially the same as in green sand except in respect to the actual manipulation of the sand used, as the composition and general properties of the two sands are very different. For dry sand moulding, the mould requires to be thoroughly dried in a suitable stove before it can be cast successfully. Dry sand mixture such as 90 per cent. floor sand and 10 per cent. Leavenseat sand containing 12 per cent. clay, incorporates no combustible substance, such as coal dust or blacking, but these are used in the green sand mixtures. They are much stronger, however, and more binding, but too close and compact when in the damp state to permit of the escape of gases generated by the heat when casting. After being thoroughly dried, the moulds become harder and stronger. These and other factors make the dry sand process more reliable, especially for larger and more important work.

In green sand moulding there is a much greater tendency to honeycombing and the production of unsound castings. Honeycombing which usually appears at the top side of the castings, is often due to the water arising from the dampness of the green sand, being evaporated into steam, which for the want of a freer escape finds its way through the liquid metal where it has become entrapped. By hammering or breaking up, such defects are all the more liable to occur in the vicinity of the studs or chaplets, especially those placed on the top for holding down cores. This again is due to steam vapour being in the first instance condensed on these metal surfaces and then evaporated by heat of the molten metal, in contact with it during the casting process. The sand in a green sand mould is much weaker than by the dry sand mixture and is therefore more readily broken by the wash of the metal, and any portion thus separated will cause sand holes or scabs.

Having regard to all the circumstances and the very important fact that these castings are made by semi-skilled labour and are machine moulded, more success is obtained in the dry sand than the green sand process.

Operations Performed by Moulding Machines

Owing to the increased competition in founding, coupled with the large and growing demand for castings, much time and ingenuity have been expended in devising mechanical devices that will replace, to some extent, the manual labour involved in the foundry, particularly in such classes of work as loose patterns and plate moulding. The result of the employment of such devices has been to cheapen and increase the output, at the same time securing a more uniform and higher quality of work. While these good results will continue to obtain in repetition or standard work where the objects are of a more or less simple form, there will always be a demand for skilled moulders to deal with the many special lines of work which will continually recur, and which it will not be commercially possible to attempt to handle by machine.

With the exception of the locomotive cylinders all the engine detail castings are moulded on a large Osborne jarring machine by semi-skilled labour—two men and a boy. One man closes the moulds, and the other blacks the moulds and assists the boy at the machine. After a time on the machine, these men become very efficient and competent at their work, and when exceptional circumstances arise, such as a man being off duty, it has been found to be good policy to put an unskilled man on the machine. It is always giving him a certain amount of knowledge of the machine, and will make him ready to take over when there is a vacancy for a machineman. It also serves the purpose of maintaining the output and keeping the core-making and fettling sections in the department fully employed.

FIG. 1.—METHOD OF GATING PISTON VALVE LINERS.

FIG. 5.—EXTERNAL CORES ASSEMBLED FOR CYLINDER.

FIG. 10.—PLAN VIEW OF ASSEMBLED CORE.

FIG. 11.—CLOSED READY FOR RAMMING HEADS.

Gating

The gating is a very important factor in the manufacture of good clean castings. All gates are placed on the moulding boards by the patternmaker to the instruction of the foreman moulder, who gives the sizes and direction of all rates and risers. As shown in Fig. 1 for the piston valve liners, the gates are so placed that the metal runs directly below the ports and exhaust. This method clears away any scum or dirt that may lodge in this section during the casting operation. It is very important that these parts should be clean and free from scum or dirt, as the ports are cored out leaving $\frac{1}{16}$ in. machining allowance, and the least spot or mark would cause these castings to be rejected.

FIG. 3.—THE CORE PLATES USED ARE MACHINED.

Piston heads are run with two drop gates on the rim and the riser placed on the highest part. With the dry sand process, and attention paid to the proper method of gating and pouring the metal at a high temperature, say from 1,320 to 1,340 deg. C., good high-pressure castings can be obtained.

* A Paper read before the Edinburgh Section of the Institute of British Foundrymen.

Core Making

This section is a very important part of the foundry department. The core shop has conveniently-placed portable racks (Fig. 2) with ample storage capacity readily accessible to the core makers. They are placed between the core benches, with a passage of 3 ft. on both sides. These racks consist of a series of open and narrow shelves which allow the cores to be deposited on the one side by the core makers; when these are filled up with cores, they are taken by a lift truck, with a capacity of 2,500 lbs. and 1⅝ in. lift, and placed in the drying store.

FIG. 4.—FIRST CORE ASSEMBLED FOR OIL SAND MOULDED CYLINDER CASTINGS.

Core Plates

The cores are made in half and are supported on iron plates. These iron plates, known as core plates, have a true-planed surface. If warped plates were used for drying the half of jointed cores, it would be found necessary to rub the faces of the cores together until they make a good joint, but this is a bad practice, as it will be found that such cores are usually out of shape, and consequently will not produce satisfactory castings. It is therefore good practice to have all core plates with a true planed surface (Fig. 3).

Sand Mixtures Used

All cores are made in oil sand. There are three different mixtures of core sand: for cylinders and engine detail cores a mixture of 150 lbs. sea sand to 8 lbs. of linseed-dextrene mixture is used; for axle boxes and less important cores a mixture of 150 lbs. of sea sand to 5 lbs. of linseed-dextrene mixture is used. All brake block cores are made with 150 lbs. of reclaimed sand to 5 lbs. of No. 2 binder, L.M.S. specification.

FIG. 8.—SHOWS SPACE AROUND THE ASSEMBLED CORES FOR SAND RAMMED BETWEEN THE CORES AND BOX.

The core sand is mixed in the pan mill, the sand being first measured into the mill, and the oil and other binding materials then added. When mixed it is taken and distributed to the core makers at their benches, particular attention being paid to the green sand bond, which gives some idea as to the quality of the sand. As far as possible, the same men are retained for sand mixing. The millman has in his possession the standard mixtures and no mixtures are altered unless authorised by the works metallurgist or foreman. Continuous application enables these men to become expert at this work, and the result is a very uniform core sand.

The savings obtained from a good oil-sand mixture are not only to be associated with a simple method of making all cores, due to the cores being made in half, but also are due to the elimination of all cast-iron core-irons.

Oil Sand Cylinder Moulds

An experiment was made recently in manufacturing a locomotive cylinder in oil sand without the use of the ordinary pattern. Three core boxes were used to make ten external cores, by transferring the parts required to each corebox. The method adopted was to make a level bed on the drag part of the moulding box, and place the bottom core on the centre lines, the cores being made 4 in. clear of the inside of the moulding box, and all runners and risers rammed in the cores. When the five bottom cores were in position, the mid-part of the moulding box was lowered over them and ordinary floor sand rammed round the cores to hold them in position. There was no danger of the cores being rammed out of position as the joints had been checked in the cores to prevent any shift when ramming. The bottom part of the mould, when completed, was ready to receive the cores for the internal surfaces. Care was taken in locating these cores in order that their distances from the adjacent sand surfaces and the ultimate thickness of the metal mould be uniform. When all the internal cores were in position, the remaining five external cores were placed in position, and the mould closed up. The top part of the moulding box was lowered over the cores and rammed up similarly to the drag part.

The mould was then prepared for pouring in the molten metal. A runner box connected the two down gates through which the metal would flow. These holes were plugged with two pieces of tin with a ¼-in. hole in the centre. This allowed the runner box to be filled with metal before the metal passes to the mould. The two down gates fed the casting equally from the two corners. The process is shown in Figs. 4-11.

The casting referred to was an 18 in. by 26 in. freight engine cylinder, the weight of which was 23 cwts., but 28 cwts. were required in the process of casting. It took two days for the metal to cool sufficiently to allow the casting to be taken to the dressing shop. This was necessary to prevent uneven stresses which would be set up in the casting if allowed to cool quickly and prevented any chilling and hardening effect on the surfaces to be machined. When taken to the dressing shop the casting was easily fettled, all the external cores falling off, leaving a very clean surface. The benefits obtained from this process are that it is a simple method, there is no danger of scabbing of the mould, as the whole mould is perfectly dry, there are no crushes in the mould when closing, there are good joints, and the mould is visible through the whole process of closing. Twenty of these cylinders have been made and machined and the results have been satisfactory.

FIG. 6.—INTERNAL CORES IN POSITION.

Axle boxes and carriage and wagon castings are manufactured by machine moulding by the green sand method. The preparation of sand for green sand moulding involves the following: The facing sand is made from 80 per cent. floor sand, 10 per cent. Levenseat sand and 10 per cent. coal dust. This sand is milled in the pan mill, giving the sand the bond strength for facing the moulds. The floor sand is put through a Royer sand machine, which not only gives a good mixing, but aerates the sand, and imparts a high permeability. For heavy and light jobbing castings made in green sand, the facing sands are shovel mixed with a percentage of floor sand, rock sand, Belfast sand and coal dust.

FIG. 7.—DRAG MOULD OF A CYLINDER MADE FROM OIL SAND.

A series of tests on the moisture content of moulding sand in various parts of the foundry has been made by the works metallurgist, by means of a Speedy moisture tester. The results show a variation through the foundry of the moisture content in the sand. In green sand, the tests showed the moisture from 7 to 9 per cent., and in dry sand 9 to 10 per cent. by weight. The result of these tests shows the importance and need for mechanical control of all moulding sands.

Casting Temperature for Cast Iron

As a result of a discussion with the works metallurgist as to what was the correct temperature at which cast iron should be poured, the results of some tests recently made in the iron foundry, St. Rollox, to determine the effect of casting temperature on the mechanical properties of cast iron are detailed below.

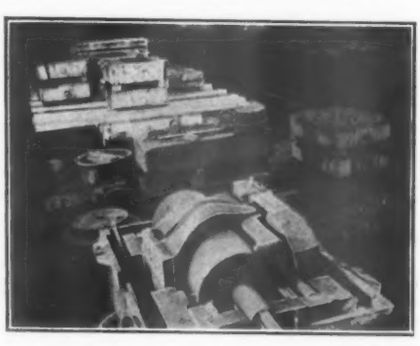

FIG. 9.—END VIEW OF FIG. 7.

A series of 2 in. by 1 in. section test bars was cast in dry sand moulds from the same bogies at temperatures of 1,330, 1,320, 1,280, 1,250, 1,220 and 1,180 deg. C. The metal used was cylinder quality, and three 42 in. bars were cast at each temperature. Each bar was tested in transverse between 36 in. centres. The test was repeated on the broken pieces between 12 in. centres, and result was made equivalent to the

(*Concluded on page* 410)

The Production of Nickel-Chrome-Molybdenum Steel Castings from a Bessemer Converter*

BY J. FLACK.

Most of the nickel-chrome-molybdenum steels were made by the crucible, open-hearth or electric furnace processes, and the converter process was introduced experimentally, but proved so successful that it can now compete with the other processes as a commercial proposition.

Plant

The plant used in one particular shop consists of an ordinary cupola working in conjunction with a brick-lined acid Tropenas Bessemer converter. A suitable charge consists of 50 per cent. hematite pig, 40 per cent. good scrap, and 10 per cent. shop scrap. It is extremely important to keep the sulphur and phosphorus low, as later, if these are excessive, besides being detrimental to the structure of the steel, they combine with the molybdenum and enter the slag as sulphides and phosphides of molybdenum, resulting in an uneconomic loss of molybdenum. When the charge in the cupola is melted and the metal is hot and fluid, it is tapped into the converter. The converter is then blown and the manganese, silicon and carbon are oxidised. The blowing or oxidising ceases when carbon is down to about 0.1 to 0.15 per cent., which is judged by the condition of the flame at the converter mouth.

After blowing, the manganese, silicon and carbon are added in the usual way—the manganese and silicon as ferro-alloys, the carbon as a definite weight of cupola metal of known carbon composition, then the nickel as nickel shot, the chromium as ferro-chromium, and the molybdenum as ferro-molybdenum. They are placed in tin canisters, immersed in water and thrown into the converter; thus they pierce the slag and thoroughly disseminate throughout the mass of the steel. After allowing five minutes for the steel to become thoroughly homogeneous, the metal is poured into a brick-lined ladle and transported into the foundry for casting.

The amount of alloys added depends on whether the castings are required for toughness, hardness or wearing qualities. If hardness and wearing is called for, the carbon, manganese and chromium are kept rather high. If strength without extra hardness is required, they are kept lower, say C 0.25, Mn 0.5 and Cr 0.6 per cent. The quantity of nickel and molybdenum does not affect these properties, the nickel being 1 to 4 per cent. and the molybdenum 0.25 to 1 per cent. It might be added that the converter metal must be very hot, as the alloys lower the temperature and fluidity of the steel.

Moulding and Foundry Conditions

The moulding and design of castings are the same as for ordinary carbon steel, as the shrinkage, contraction, gas evolution, etc., are the same. In this particular foundry, small castings are cast in oil-sand moulds by the blocking-out process. The oil-sand mixture consists of ordinary sea sand bonded with an oil compound known as Baltiseed oil. For larger castings, naturally-bonded North Wales red sand is used, mixed with 50 per cent. oil sand, the moulds being painted with a weak solution of core gum.

As regards casting, no additional care is required, except that the alloy steel may be slightly more viscous. In this shop the moulds are cast from a 2-ton capacity bottom pouring ladle. Castings varying from a few pounds to 2 tons in weight can be cast from the same ladle.

Heat-Treatment

When the castings in the moulds have cooled sufficiently, they are stripped and charged immediately into an annealing furnace, in this case an ordinary coke-fired oven. An annealing temperature of 900 deg. C. is reached, and the castings are thoroughly soaked at this temperature and allowed to cool to normal temperature before opening the furnace. One of the chief dangers is temper-brittleness. Nickel and chromium increase temper-brittleness, but if molybdenum is present to the extent of more than 0.5 per cent., it entirely eliminates this phenomenon.

The steel is gradually heated up to 870 deg. C. and held at that temperature only sufficiently long to ensure thorough soaking. The castings are then removed from the furnace, and quenched in oil as quickly as possible. At this point the steel is hardened and the tensile strength and Brinell hardness are at a maximum, but other properties are not at their best. To obtain maximum values for all the physical properties, the steel is then tempered. The temperature for this depends on what the steel is required for. If greater tensile and Brinell values are required, the temperature is lower than if a better elongation and ductility are necessary. The temperature ranges between 500 and 670 deg. C., the steel being held at that temperature for 2 hrs. and then slowly cooled in air.

A test-bar heated to 870 deg. C., quenched in oil and then tempered at 500 deg. C. gave the following values:—63 tons per sq. in. tensile; elongation, 18 per cent.; Izod test, 42 ft.-lbs.; 50 per cent. reduction in area; and Brinell hardness, 280. It might be added that this steel machined quite easily even after tempering, and presented no difficulties in this direction.

Structure

The effects of the nickel, chromium and molybdenum completely alter the structure of the steel. Chromium and molybdenum are carbide formers, and this accounts for the greater hardness than in an ordinary carbon steel, and the nickel is a "strengthener," giving a smaller grain size. The nickel also tends to counteract carbide formation, thus checking any tendency to excessive hardness. Molybdenum is the only alloy that has been tested and proved successful for stopping "creep."

Types of Castings

The following types of castings are made:—Brake drums and brake accessories for heavy transport vehicles; gear-wheels of all types; rollers for oil-cake mills, etc.; marine castings for both mercantile and Admiralty vessels, such as rudder frames, propeller shaft brackets, and submarine hatch covers. These castings all give great satisfaction and more than justify the increased cost of production.

* An entry in the Short Paper Competition held by the Birmingham Branch of the Institute of British Foundrymen recently.

Metallisation of Machine Elements

Metallising, the method of spraying molten metal so that it will adhere to a solid base, brings to the fore practical questions regarding strength of bond, effects of heat-treatment, effectiveness against corrosion and practical limits of coating cylinders of small diameters. A number of tests have served to throw light on some of these problems. Information concerning machinability has been obtained by taking two steel rods 10 in. long and 2 in. in dia., which were machined at the centre to 1½ in. in dia. and 4 in. long. These rods were sprayed immediately after the machining operation to a thickness of approximately 0.010 in. One rod was sprayed with high-carbon wire and the other with low-carbon wire. They were then placed in a lathe, about ¼ in. off centre, and were turned until the base metal could be seen. On the high-carbon steel specimen the sprayed metal tended to tear away from the surface, this tendency increasing with a heavier cut. It was noted that high-carbon steel, as sprayed, was very hard and difficult to machine. The low-carbon sprayed steel seemed to give slightly better bond than the high-carbon steel, although with regard to other characteristics it behaved quite similarly. However, the low-carbon wire, as sprayed, can be machined without difficulty.—"The Iron Age."

Propellers for the "Queen Mary"

Four "Turbiston" bronze propellers have been supplied for the "Queen Mary" by J. Stone & Company, Limited, two as working propellers and two as spares. These propellers are the largest solid-type bronze propellers in the world, exceeding the next heaviest by over 10 tons each. For the casting of each propeller over 53 tons of "Turbiston" bronze was poured, the finished weight being 35 tons. The propellers are 4-bladed, the diameter being nearly 20-ft., and the cone caps, which are also made of the same alloy, weigh nearly 1 ton each. It is interesting to note that these propellers were made in the same works at Charlton as propellers for the record-breaking Atlantic liners "Normandie," "Bremen," "Europa," and "Mauretania."

Manufacturing Details

No patterns were used in the accepted sense of the word, but the mould was built up of brick and loam, entailing the use of 15,000 bricks, 20 tons of sand, and 30 tons of iron and steel, whilst the completed mould weighed over 100 tons. This mould was lowered into the casting pit, and into it more than 53 tons of "Turbiston" bronze were poured through the runner boxes, which controlled the flow. Although the actual pouring took less than 20 minutes, it was necessary for the propellen casting to be left in the pit for about 10 days to ensure correct cooling.

The casting was then transferred to a special boring mill, weighing over 165 tons and built on a solid foundation of 200 tons of concrete. By means of this mill, machining operations were carried out in the following sequence:—(1) Cutting off the head or riser which weighed approximately 10 tons (the 6-ft. diameter circular saw used for this operation is the largest yet employed for cutting through metal); (2) facing of the boss fore and aft; (3) boring the boss to take the propeller shaft, and (4) cutting of the keyways. The propeller was then transferred to a unique propeller planing machine, and the blades planed true to pitch. Finally, it was polished all over by rotary grinders and polishers, and when finished had a mirror-like finish. Each propeller was subjected to a severe test on a balancing device, whereby a light touch of the finger on the tip of the blade would move or stop the propeller as desired.

The transport of the propellers was a difficult problem owing to their large weight, 35 tons each, plus 10 tons, the weight of the lorry, and it was necessary for the transport to be done at night. Special police permits had to be obtained, and indemnities furnished to all highway and bridge authorities over whose highways or bridges the propellers passed. For the purpose of comparison, the weights and diameters of Stone's "Turbiston" bronze propellers fitted to other large liners, are given as follow:—

Ship.	Casting weight.	Finished weight.	Diameter.
	Tons.	Tons.	Ft. Ins.
"Queen Mary" ..	53	35	20 0
"Normandie" ..	37	23¼	16 0
"Mauretania ..	29	18½	16 9
"Majestic" ..	30	15½	16 6
"Bremen" ..	35	18¾	16 5
"Europa" ..	27	14	15 0

Nitrogen Absorption by Mild Steel

H. J. WIESTER, in a Paper in the "Archiv für das Eisenhüttenwesen," describes experimental work showing that structural characteristics of insufficiently-polished sections of mild steel are due to the absorption of atmospheric nitrogen by the top surfaces during the polishing process. A contributory factor is the crushing of the surface layer.

Heat-Treatment of Cast Iron by Hardening and Tempering*

By J. E. HURST

"To harden cast iron.—Heat the article to a bright red heat, and quench in a mixture of 3 galls. of water, ½ pint of oil of vitriol and 2 ozs. of saltpetre. Another mixture for quenching consists of salt water, 10 galls., salt 1 peck, oil of vitriol ½ pint, saltpetre ½ lb., prussiate of potash ¼ lb., cyanide of potash ½ lb., by repeating the process cast iron may be made harder." (Quotation "WORKS MANAGERS' HANDBOOK," Walter S. Hutton, 1901.)

One of the many outstanding developments in the metallurgy of cast iron, which have occurred during recent years, is its heat-treatment by hardening and tempering. As a means of obtaining hardened cast-iron wearing parts for machinery, heat-treatment by hardening and tempering is now practised extensively, and it is fully understood that such treatments can be applied without the risk of any deterioration in the mechanical properties. It is this knowledge, arising out of recent research and investigations, upon which the claim rests for hardening and tempering cast iron as a modern development in the field of the metallurgy of cast iron.

Quotations from practical workshop handbooks, of which the one used as a text to this Paper is typical, show that attention has been given to the hardening of cast iron by quenching for a long time. The British Patent records contain references to the hardening of cast iron. An early one, dating back to the year 1839, recommended that cast iron be heated to a blood red heat and quenched in water containing green vitriol or alternatively alum, saltpetre and prussiate of potash. It is of some general interest to record that the majority of these early references apparently attach great importance to the quenching media and a wide variety of different types of solutions embodying different salts, mixtures of salts and acids have been recommended.

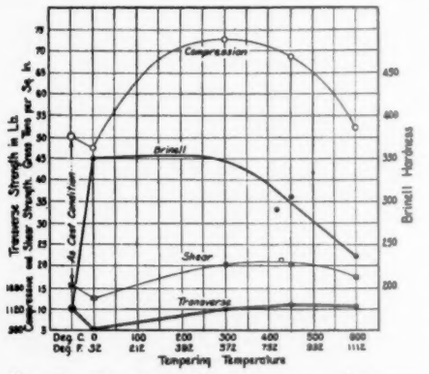

FIG. 1.—EFFECT OF HARDENING AND TEMPERING ON STRENGTH PROPERTIES (GUILLET).

It is clear from modern research work that all these old processes would be successful perhaps in securing increased hardness. However, as none of these old mixtures appears to embody tempering treatments subsequent to hardening, it is to be presumed that the important effect of tempering in restoring the strength properties, which are impaired by the quench-hardening treatment, was unknown.

Effect of Hardening and Tempering on Mechanical Strength Properties

This knowledge of the influence of suitable tempering treatments applied to cast iron in the quench-hardened condition in restoring and even improving the mechanical strength properties, appears to be due entirely to modern research work, principally the writer's own investigations.[1]

Effect of Hardening on Strength.

The results of these investigations show that, when cast iron is subjected to hardening treatment by heating to temperatures above the A_1 critical point, and quenched in a suitable media, either water or oil, an increase in hardness accompanied by a marked drop in ultimate breaking strength, either in tension, compression, shear or transverse loading, results. The magnitude of the increase in hardness varies, of course, with the chemical composition and the structural condition of the particular cast iron treated; but the increment in hardness may be over 100 per cent. greater than the original "as-cast" condition. In a like manner, the magnitude of the decrease in ultimate breaking strength varies according to particular conditions, but it can be of a very serious order and reductions of over 50 per cent. in the ultimate strength value under conditions of transverse bending have been observed in quenched specimens.

REFERENCES

1 Hurst, J. E., "Oil-Hardening and Air-Hardening Cast Iron," Proceedings, Institute of British Foundrymen, vol. 24, p. 373 (1930–31), and "Hardening Cast Iron, Hardened and Tempered Cast Iron, Nitrogen Hardened Cast Iron," vol. 25, p. 146 (1931–32). FOUNDRY TRADE JOURNAL, vol. 45, p. 345 (1931). Guillet, Gallibourg and Ballay, Comptes Rendus, 1930, p. 538. Also Investigations of F. B. Coyle, O. W. Potter, Piwowarsky, Durant, Grotts, Botschwar, Everest, Shore, Eddy and others.
2 Hurst, J. E., Journal, Iron and Steel Institute, No. 1 (1933).
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6 Schwartz and Vath, Giesserei, vol. Zl, p. 345 (1934).
7 Hurst, J. E., FOUNDRY TRADE JOURNAL, Dec. 3, 1931, and "Iron Age," Oct. 26, 1933.
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9 British Patents Nos. 342,334 and 342,335.

Effect of Tempering on Strength.

Tempering the quench-hardened specimens is accompanied by a recovery in the ultimate breaking-strength value, and all the investigations show that this recovery increases uniformly with increasing temperature until a maximum is reached, followed by a decline with still further increment in tempering temperature. This phenomenon is accompanied by a decrease in Brinell hardness, and the general effect of quench-hardening and tempering on the hardness value and strength properties is illustrated in Fig. 1.

Effect of Hardening Plus Tempering on Strength.

Some idea of the magnitude of the influence of hardening and tempering on the hardness and ultimate breaking-strength values is obtained from Figs. 2 and 3. These embody the actual test results on a series of specimens of centrifugally-cast, chromium-alloy cast irons containing varying amounts of phosphorus in accordance with the chemical analyses given in Table I. Fuller details of the actual experimental procedure followed are to be obtained by reference to the original Paper.[2] The quench-hardening effect has been obtained by quenching the specimens in oil from a temperature of 875 deg. C., and it will be seen that in this condition an increment in hardness of from 244 to 534, nearly 100 per cent., has been obtained in the low phosphorus specimen. In the case of ultimate breaking strength in the same specimen, an increment of nearly 23 per cent. from 21.9 to 26.8 tons per sq. in modulus of rupture stress was recorded.

In this connection, Fig. 4 shows the variation in strength results for these same specimens, plotted against the tempering temperature. The strength properties in the "as-cast" and hardened conditions included in the same diagram show the effect of the quench-hardening treatment in lowering the strength values and also the restoration of the strength after tempering, attaining a maximum value in excess of the original "as-cast" condition is clearly indicated. This improvement in the strength properties of cast iron in the hardened and tempered condition is the outstanding discovery arising out of recent research work, and in that it has led to the establishment of confidence in the strength properties of hardened and tempered cast irons, it has been of pre-eminent importance in the commercial development of this method of hardening cast irons.

TABLE I.—*Analyses of Specimens of Varying Phosphorus Contents.*

Spec. No.	T.C. per cent.	C.C. per cent.	Gr. per cent.	Si per cent.	Mn per cent.	P per cent.	Cr per cent.
1	3.39	0.52	2.87	2.21	1.07	1.56	0.52
2	3.49	0.49	3.00	2.16	1.08	1.30	0.71
3	3.44	0.30	3.14	2.44	1.01	1.06	0.59
4	3.55	0.46	3.09	2.35	1.00	0.63	0.61
5	3.58	0.39	3.19	2.44	0.93	0.58	0.62
6	3.60	0.54	3.06	2.44	1.09	0.43	0.55
7	3.81	0.59	3.22	2.49	1.02	0.035	0.61

Condition and Analysis

Recently it has been shown[3] that the magnitude of maximum improvement in strength results due to hardening and tempering, is to an extent dependent upon the condition, whether sand cast or chill cast, and also upon the chemical composition, particularly as regards the total carbon and silicon contents. The effect of these conditions is demonstrated by Figs. 5 and 6. The experimental work upon which these diagrams are based was carried out on a series of cast irons of the compositions shown in Table II.

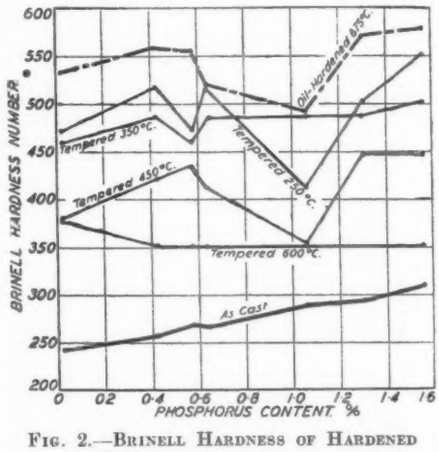


FIG. 2.—BRINELL HARDNESS OF HARDENED AND TEMPERED SPECIMENS OF VARYING PHOSPHORUS CONTENTS.

The specimens were quench-hardened in oil from a temperature of 850 deg. C., and tempered in the usual manner. Fig. 5 is divided into three zones and shows the relation between the total carbon and silicon contents in sand-cast material which yield improvements in strength properties of something less than 5 per cent. (zone 1), 5 to 10 per cent. (zone 2) and over 10 up to 20 per cent. (zone 3). Fig. 6 is of particular interest in that, in addition to showing the limit of total-carbon plus silicon contents in both sand-cast and chill-cast material beyond which very small improvement in strength

* Exchange Paper of the Institute of British Foundrymen presented at the Annual Convention of the American Foundrymen's Association, held in Detroit, May 4 to 9. The Author is President of the Institute of British Foundrymen and technical director, Sheepbridge Stokes Centrifugal Castings Company, Limited, Chesterfield, and Bradley & Foster, Limited, Darlaston.

properties is obtained, it also shows the greater magnitude of increment in the strength properties in the chill-cast material due to hardening and tempering. Even in the chill-cast material there appears to exist a maximum of total-carbon plus silicon contents, which is at a higher value than in the case of the sand-cast specimens, beyond which there is a reduction in the magnitude of the improvement in strength results.

It is of importance to bear in mind that the test results given in connection with centrifugally-cast material throughout this Paper are obtained on material cast in metal moulds and as such are to be regarded as coming within the category of chill-cast material.

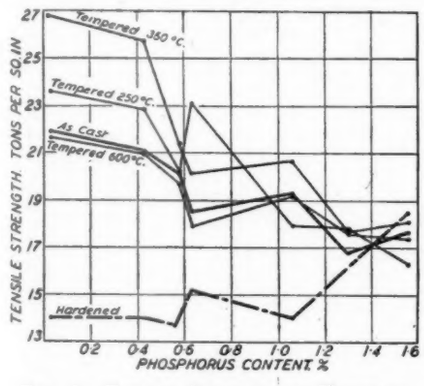


FIG. 3.—TENSILE STRENGTH OF HARDENED AND TEMPERED SPECIMENS OF VARYING PHOSPHORUS CONTENTS.

Stress-Strain Relationships

An important aspect of the strength properties is the study of the stress-strain curves and some attention has been devoted to the influence of hardening and tempering upon the character of the stress-strain relationships. In Figs. 7 and 8, the stress-deflection curves determined upon annular ring specimens are shown for the series of centrifugally-cast specimens detailed in Table I. The curves in Fig. 7, taken from the specimens in the " as-cast " condition, are characteristic and show an increasing amount of plastic deformation with diminishing phosphorus content, as indicated by the curvature in the upper portion of the curves. Fig. 8 shows curves for the same specimens in the hardened and tempered condition, tempered at 350 deg. C., the condition corresponding to the maximum increment in strength in the lower phosphorus members of the series.

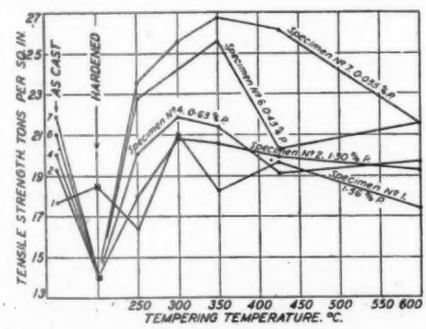


FIG. 4.—TENSILE STRENGTH-TEMPERING TEMPERATURE RELATIONSHIP, AS CAST, HARDENED AND TEMPERED.

One of the outstanding characteristics is the reduction in curvature and consequently the reduction in plastic deformation during the breaking. This is further exemplified by the reduction in permanent-set value indicated in Fig. 9. This is apparently a characteristic effect of hardening and tempering cast iron and is an effect of some industrial importance (*e.g.*, where cast iron is used as a spring in the case of piston rings and where it is subjected to the repeated applications of stress).

If the included areas of the stress-deflection curves are accepted as a measure of the resilience and as a comparative measure of the toughness as opposed to brittleness, these curves clearly indicate an increase in included area and consequently in toughness due to hardening and tempering. With increase in tempering temperature beyond that at which maximum strength properties are obtained, the curves tend to become more nearly as the original " as-cast " condition, but in general they rarely become identical. Even when the same hardness value after tempering as in the " as-cast " condition is reached, the material shows less permanent set and less plastic deformation characteristics, particularly in the lower phosphorus members of this series.

TABLE II.—*Chemical Composition of Specimens (Piwowarsky).*

No.	T.C. per cent.	Gr. per cent.	C.C. per cent.	T.C. + Si per cent.	Mn per cent.	S per cent.	P per cent.
1	2.40	1.46	0.94	4.9	0.28	0.070	0.040
2	3.28	2.80	0.48	5.5	0.43	0.019	0.062
3	4.08	3.40	0.68	5.8	0.54	0.020	0.066
5	2.70	0.92	1.78	4.2	—	—	—
6	2.04	Traces	2.04	3.9	—	—	—
4*	3.12	2.60	0.52	5.4	0.39	0.020	0.062

* Also contained 1.77 per cent. nickel and 0.53 per cent. chromium.

TABLE III.—*Chemical Analyses of Centrifugally-Cast Specimens of Varying Phosphorus Contents and Fine Graphite Structures.*

Sample No.	T.C. per cent.	Gr. per cent.	C.C. per cent.	Si per cent.	Mn per cent.	P per cent.
1	3.49	3.49	Nil	2.49	0.55	0.022
2	3.47	3.28	0.19	2.49	0.59	0.526
3	3.52	3.03	0.49	2.63	0.41	0.560
4	3.49	2.79	0.70	2.58	0.63	0.660

Effect on Modulus of Elasticity.

The study of the modulus of elasticity (EN value) in the above specimens shows that in the " as-cast " condition, this value shows a marked and steady increase with increasing phosphorus contents. In the hardened and tempered conditions, an increase in the phosphorus is accompanied by an increase in the EN value, although the effect of these treatments is to lower the general level of the value. Tempering at the higher temperature is accompanied by a recovery of this property in the direction of the " as-cast " condition. The fall in value is greatest in the lowest phosphorus specimens and an increase in phosphorus appears to minimise the reduction in value due to this cause.

TABLE IV.—*Mechanical Properties of Specimens as Detailed in Table III.*

Specimen No.	As cast	OQ* 875 deg. C. Temp.† 275 deg. C.	OQ* 875 deg. C. Temp.† 450 deg. C.
Modulus of rupture, tons per sq. in.			
1	22.8	48.20	44.50
2	27.2	42.50	43.50
3	28.0	41.25	43.30
4	23.2	37.30	36.20
Modulus of elasticity, lb. per sq. in. × 10^6.			
1	16.1	15.50	14.10
2	16.6	14.40	15.30
3	17.5	16.90	16.10
4	15.7	15.50	15.60
Permanent set, per cent.			
1	9.95	3.56	5.00
2	21.7	7.70	5.00
3	15.1	6.25	5.35
4	22.2	5.85	4.70
Brinell hardness			
1	163	474	412
2	196	488	390
3	207	412	380
4	196	435	423

* Oil-quenched. † Tempered.

Mechanism of Hardening and Tempering

The examination of quenched and tempered specimens under the microscope shows that, exactly as in the case of steels, the hardening effect is due to the formation of martensite and the effect of tempering at successively higher temperatures is accompanied by a gradual change from martensitic to sorbitic structures. It is of some theoretical and general interest to note that the hardening effect in cast irons is not of necessity proportional to the amount of combined carbon present initially and that the hardening effect can be obtained in specimens in which, prior to the heat-treatment, combined carbon is completely absent.

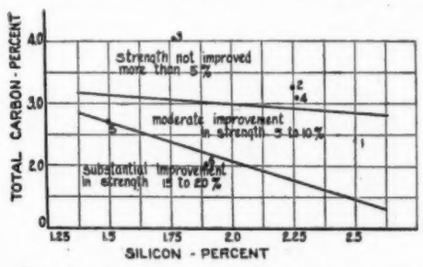

Strength not improved more than 5%
moderate improvement in strength 5 to 10%
substantial improvement in strength 15 to 20%
TOTAL CARBON - PERCENT
SILICON - PERCENT

FIG. 5.—RELATION BETWEEN CARBON AND SILICON CONTENTS AND IMPROVEMENT IN STRENGTH RESULTS DUE TO HARDENING AND TEMPERING (PIWOWARSKY).

Effect of Combined Carbon.

This was demonstrated first by the hardening and tempering of specimens in which the combined carbon initially present had been completely decomposed by a drastic annealing treatment. In some experiments of this nature,[4] the annealed specimens showing no combined carbon on analysis responded just as readily to the hardening and tempering treatments as did the specimens in the " as-cast " condition containing substantial amounts of combined carbon.

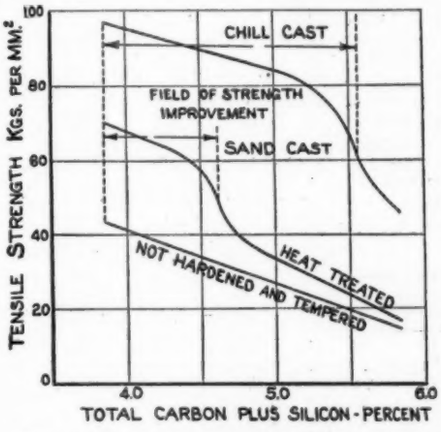


FIG. 6.—DIAGRAM SHOWING RELATION BETWEEN TOTAL CARBON PLUS SILICON CONDITION AND FIELD OF STRENGTH IMPROVEMENT.

Similarly, the series of specimens detailed in Table I responded to hardening and tempering after a preliminary drastic annealing treatment at 900 deg C., although some irregularity in the extent of the hardening was noted, particularly in the high phosphorus-content specimens.

An additional example is of interest. It is taken from the series of specimens whose

chemical composition is given in Table III. This again is a series of centrifugally-cast specimens of varying phosphorus contents and, in the low-phosphorus specimen No. 1, the chemical analysis shows the complete absence of combined carbon. The hardness results in Table IV show clearly that this specimen has hardened to even a greater degree than the specimens containing an initially higher combined-carbon content. As a matter of fact, in this specimen, although the chemical analysis showed combined carbon to be completely absent, the microstructure showed the presence of very slight traces of pearlite.

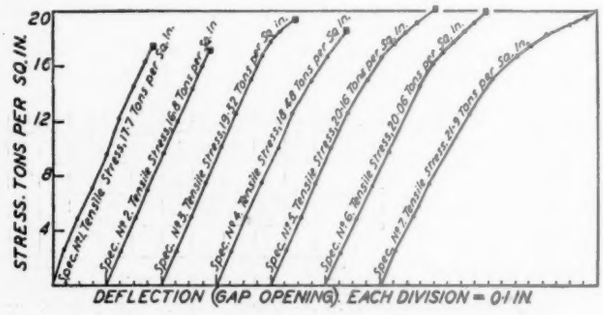


Fig. 7.—Stress-Deflection Curves, As Cast.

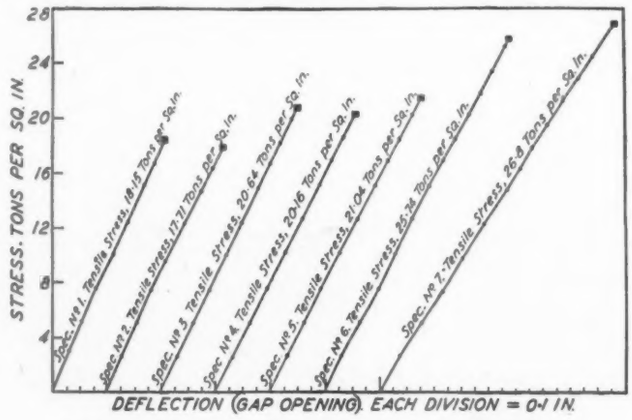


Fig. 8.—Strength-Deflection Curves, Hardened and Tempered at 350 deg. C. (662 deg. Fah.).

To ensure that hardening could take place in the complete absence of pearlite, specimens from the same castings were drastically annealed at 950 deg. C. for a total period of 16 hours heating and cooling, and even with the complete absence of initial pearlite, the specimens were found to respond to the hardening and tempering treatment. The microstructures are shown in Fig. 10. It would appear from results of this nature that the hardening effect may be brought about in part by the solution of the graphite.

It is known that on heating to temperatures of 900 to 950 deg. C., some portion of the graphite can be redissolved and retained in the martensitic condition by quenching. This was shown by the author as far back as 1917,[5] and it is clear that this effect must be taken into consideration in the formulation of any conception of the mechanism of quench-hardening in cast iron.

The results of this particular experiment, in Tables III and IV and the illustration in Fig. 10, have been included with the additional object of drawing attention to the important effect of the condition of the graphite on the test results obtained. All these specimens, as indicated, were centrifugally-cast in metal moulds and attention is drawn to the very marked improvement in the ultimate breaking strength results, due to the hardening and tempering amounting to, in the case of the low-phosphorus specimen No. 1, well over 100 per cent. All these specimens, as will be seen from the illustrations, possessed structures of the ferrite-fine graphite type, in a well-developed form in specimen No. 1 and diminishing somewhat in form and magnitude in the specimens with increasing phosphorus. It is impossible to resist the conclusion that these exceptional improvements in mechanical strength properties are associated with this structural condition of the graphite. Further investigations appear to confirm this view. It is of interest to draw attention to the apparent coarsening of the graphite in specimen No. 1, particularly as a result of the annealing treatment.

Table V.—*Composition of Cast Irons—Schwartz and Vath Experiments.*

Type of iron.	T.C. per cent.	Si per cent.	Mn per cent.	S per cent.	P per cent.	Ni per cent.	Cr per cent.
Alloyed cylinder iron	3.15	1.90	0.62	0.018	0.46	1.04	0.35
Non-alloy cylinder iron ..	3.02	2.03	0.62	0.032	0.55	—	—
Foundry iron	2.99	1.92	0.62	0.030	0.73	—	—
Phosphorus foundry iron ..	3.20	2.45	0.70	0.105	1.37	—	—

Carbon plus Silicon Contents

In passing, it is worth while drawing attention to the fact that the sum of the total carbon plus silicon contents in the whole of these specimens is approximately seven, a figure considerably in excess of that contemplated by Piwowarsky in Fig. 6. In addition to providing an interesting commentary on the danger of adopting this empirical summation of total carbon plus silicon as a basis of expressing relationships in connection with the properties of cast irons, it serves to show that his conclusions are valid for a narrow range of conditions only.

The part played by the graphite not only in the magnitude of the improvement in mechanical strength properties but also in the actual mechanism of hardness as revealed by these results, is of special importance and introduces considerations and phenomena different from those experienced in the hardening and tempering of steels. In an investigation of the hardness of four irons whose compositions are shown in Table V, after quenching from different temperatures Schwartz and Vath[6] obtained the results as shown in Fig. 11.

Table VI.—*Included Areas of Stress-Deflection Curves. Varying Phosphorus Specimens.*

Specimen No. Phosphorus, per cent.	1. 1.56	2. 1.30	3. 1.06	4. .0.63	5. 0.58	6. 0.43	7. 0.035
	sq. in.	sq. in.	sq. in.	sq. in.	sq. in.	sq. in.	sq. in.
As cast	4.0	4.0	4.8	4.8	5.9	6.4	7.1
H. and T. at 250 deg. C.	3.6	4.8	4.8	8.6	6.5	8.4	11.2
„ „ 300 „	6.6	5.6	6.5	6.1	7.4	5.2	14.4
„ „ 350 „	4.5	4.6	6.1	6.4	7.5	10.9	14.5
„ „ 450 „	5.1	4.0	5.6	5.3	5.9	7.1	19.6
„ „ 600 „	4.2	4.2	—	5.2	5.8	7.2	11.1

Quenching Temperatures

Quenching from temperatures within the range of approximately 550 to 790 deg. C. in each case is accompanied by a drop in hardness from that of the orginal "as-cast" condition. From temperatures in excess of from 775 to 790 deg. C., quenching is accompanied by the hardening effect and, apparently, in these specimens and under the conditions of the experiment, the maximum hardening effect is obtained with quenching temperatures in the neighbourhood of 900 deg. C. It is known that when cast irons are heated within the temperature range of 550 to 790 deg. C., the combined carbon undergoes decomposition. It is suggested that the softening effect on quenching from these temperatures, as revealed by these results, is due to this cause, a fact which suggests that under many conditions the decomposition of the combined carbon, pearlite, initially present in the cast iron, may be a preliminary to hardening by quenching from temperatures high enough to secure the solution of the graphite thus formed.

Considerations of this nature have an important bearing upon the question of the most effective quenching temperature. It is quite conceivable that, according to the extent to which hardening is independent upon the resolution of the graphite, the quenching temperature necessary to obtain the most effective hardening, from the point of view of hardness alone, may be much further above the AC_3 point than is the case in steels. Something after this nature is apparent from the results of Schwartz and Vath, previously quoted.

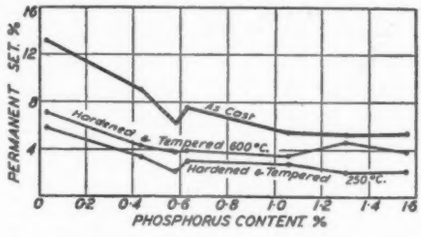


Fig. 9.—Permanent Set, As Cast, Hardened and Tempered.

In spite of this, in some careful experiments conducted by the author[7] in an investigation of the effect of quenching temperatures, effective hardening was obtained by quenching in oil from 800 deg. C., the hardness value attained being constant over a range of quenching temperatures from 800 to 860 deg. C. and actually falling slightly at a quenching temperature of 920 deg. C. The strength results obtained in these experiments after quenching and tempering at various temperatures are illustrated in Fig. 12. In the quenched condition, while the hardness was constant over a quenching range of 800 to 860 deg. C., the strength fell off substantially with increased quenching temperature.

The highest values of strength under all conditions of quenching and tempering were obtained with the lowest quenching temperatures.

It is important to add that these experiments were carefully carried out on thin specimens of centrifugally-cast material and that in actual practical experience with this same class of material, it is preferable to adopt a quenching temperature within the range of 850 to 875 deg. C.

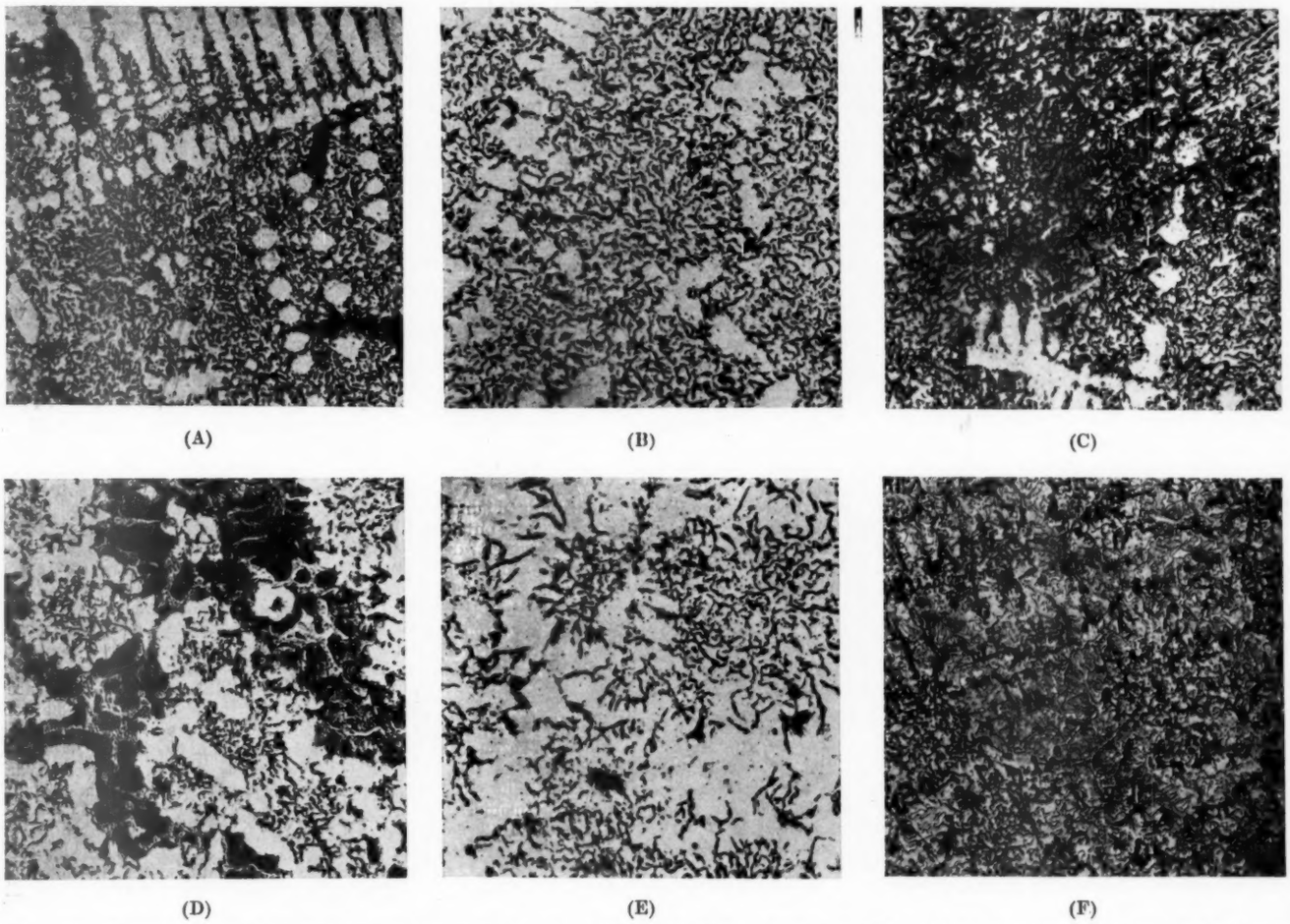
Influence of Chemical Composition and Alloy Additions

From experiments conducted on centrifugally-cast material, it has been shown that in suitable thin sections, plain unalloyed cast irons are susceptible to the hardening and tempering treatment. Of the elements present normally in cast iron, phosphorus has been systematically studied. The results referred to in the first section of this Paper have been largely taken from this study and, while the investigations were made with a cast iron containing chromium, it is probable that they can be regarded as indicating the characteristic influence of phosphorus.

Effect of Phosphorus

The range of phosphorus content studied was from 0.035 up to 1.56 per cent., and while the hardening effect after quenching and tempering was obtained with all phosphorus contents, the most uniform results were obtained with the lower phosphorus content materials. This will be clear from Figs. 2, 3 and 4 and the stress-deflection curves in Figs. 7 and 8. In these specimens and under these particular experimental conditions, the best results, as measured by increase in hardness and improvement in strength properties, are obtained with phosphorus contents below 0.6 per cent.

A point that cannot be overstressed is that, by heat treatment in this manner, substantial improvement in the resilience value or toughness can be obtained. Reference to the results in Table VI, which are the numerical values assigned to the included areas of the stress-deflection curves, will be sufficient to show how substantial this can be, particularly in the lower phosphorus members of the series. Results of this nature are as remarkable as they are unexpected with cast iron and serve to show that every confidence can be placed in the strength properties of cast iron in the hardened and tempered condition.



(A) (B) (C)

(D) (E) (F)

Fig. 10.—Structures of Low-Phosphorus Specimen No. 1. Etched in Picric Acid. × 200. (A) As Cast, (B) Annealed, (C) Hardened and Tempered at 275 deg. C. High-Phosphorus Specimen No. 4, Etched in Picric Acid. × 200. (D) As Cast, (E) Annealed, (F) Hardened and Tempered at 275 deg. C.

Effect of Alloys

As would be expected, the influence of alloy additions is accompanied by marked improvements in the results obtained and, as in the case of steels, the outstanding alloying elements are nickel, manganese, chromium and molybdenum. The influence of these elements, exerted through their influence on the position of the critical point A_3 and the critical speed of quenching, is utilised to provide effects similar to those which accompany their use in steels. In the case of nickel, its important influence on the depth of penetration of the hardening effect is shown clearly by the following experimental results obtained on chill cast bar specimens of the analyses as recorded in Table VII.

Prior to hardening, all the bars were submitted to a uniform annealing treatment at a temperature of 900 deg. C. After this treatment, the Brinell hardness results on the outside surfaces of the bars were as shown in Table VIII.

Cross sections of the varying diameter bars cast, as indicated in Table VIII, were hardened by quenching in oil from a temperature of 875 deg. C. and the Brinell hardness values across the section, from the edge to the centre, determined. These results are given in Figs. 13, 14 and 15, and show clearly the influence of nickel in improving the depth of penetration of the hardening effect. In this case, 2.0 per cent. nickel ensures a hardness value of at least 375 in the centre of the 4-in. diameter bar.

Table VII.—*Chemical Analyses of Specimens of Varying Nickel Contents.*

Spec. No.	T.C. per cent.	C.C. per cent.	Gr. per cent.	Si per cent.	Mn per cent.	P per cent.	Ni per cent.	Cr per cent.
1	3.71	0.57	3.14	1.92	0.96	0.45	Nil	0.11
2	3.76	0.41	3.35	1.97	1.02	0.48	1.18	0.11
3	3.71	0.43	3.28	1.92	0.96	0.47	2.05	0.11
4	3.71	0.36	3.35	1.92	0.99	0.49	2.97	0.15
5	3.71	0.43	3.28	1.97	0.94	0.47	4.10	0.15

An important aspect of alloy additions to

cast iron for hardening and tempering is their effect on the magnitude of the improvement possible in strength properties after suitable treatment. This improvement in strength persists not only at the point of maximum strength in the hardened and tempered condition, but even

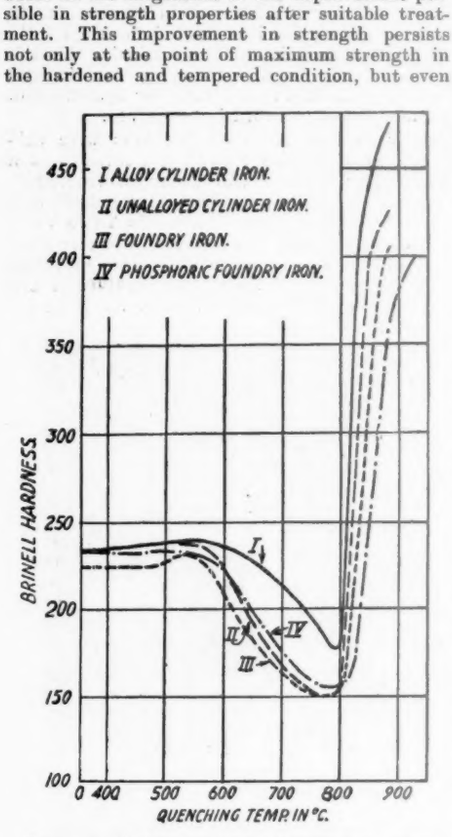


FIG. 11.—HARDNESS AFTER QUENCHING FROM VARIOUS TEMPERATURES (SCHWARTZ AND VATH).

after tempering to a hardness value equal to the original " as-cast " condition. Improvements in strength values of about 50 per cent. have been recorded.

Effect of Molybdenum on Nitrogen-Hardening Cast Iron

This is not the place to detail the results which have been obtained from various alloy cast

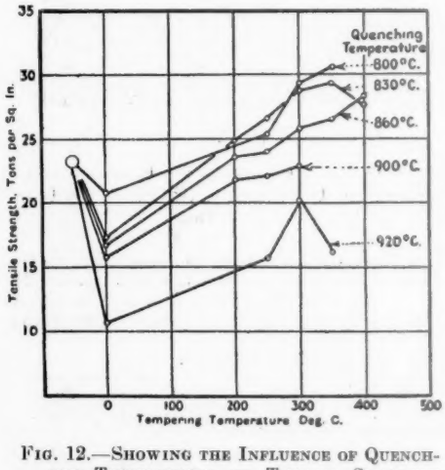


FIG. 12.—SHOWING THE INFLUENCE OF QUENCHING TEMPERATURE ON TENSILE STRENGTH AFTER TEMPERING.

iron compositions, as many results on plain, nickel-manganese, nickel-chromium, molybdenum and alloy compositions containing vanadium, aluminium, titanium and other alloy additions have been published already. However, it is impossible to pass from these considerations without making reference to the important results obtained from the joint additions of molybdenum-manganese. With combinations of manganese and molybdenum, strength values of a very high order are obtained after suitable hardening and tempering treatments.

Reference might be made here to some experimental work on the influence of molybdenum additions on the properties of an aluminium-

TABLE VIII.—*Brinell Hardness Values of Specimens in Table VII in Annealed Condition.*

Diam. of bar.	Nickel contents, per cent.				
	Nil.	1.18	2.05	2.97	4.10
1.75 ins. ..	212	217	228	207	228
4.0 ,, ..	207	196	207	212	228
5.5 ,, ..	179	187	196	187	217

chromium-nickel cast iron, after exposure to treatment at a temperature of 500 deg. C. Some of these results, which have been published already,[6] were carried out on an aluminium-chromium alloy cast iron suitable for nitrogen hardening, and it was observed that, when nickel was present particularly, there seemed to occur a marked falling off in strength properties after exposure to the nitrogen-hardening treatment at a temperature of 500 deg. C. for a period of 90 hours. These results appeared to bear some resemblance to the phenomena of temper brittleness in steels which at once suggested the possibility of exploring the influence of molybdenum. The results published already show clearly that molybdenum, either alone or in conjunction with aluminium, does not bring about any reduction in strength after low-temperature treatment under nitrogen-hardening conditions, and that it is effective also in preventing the reduction in strength under these conditions when nickel is present in the alloy.

Whilst these results were determined under nitrogen-hardening conditions, a subject outside the scope of this Paper, their apparent disclosure of the possibility of the existence of a phenomenon in alloy cast iron similar to temper-brittleness in steels is of importance in connection with the heat-treatment of cast iron by hardening and tempering, and is a discovery worthy of the attention of other investigators in this field.

Effect of Alloys on Quenching Speed

The effect of certain alloy additions in increasing the critical quenching speed can be taken advantage of in the production of alloy cast irons suitable for air-hardening treatments. A typical example[7] is the nickel-chromium alloy of the following specification:—

		Preferred composition.
Total carbon, per cent.	2.70 to 3.50	3.00
Silicon, per cent. ..	1.00 to 3.00	1.80
Manganese, per cent. ..	0.5 to 1.5	1.00
Sulphur, per cent. ..	0.14 max.	0.06
Nickel, per cent. ..	3.00 to 6.00	4.50
Chromium, per cent. ..	1.50 to 2.00	1.75

This alloy cast iron can be hardened by heating to 800 to 850 deg. C. and allowing it to cool in air and can be softened by a tempering treatment at 680 deg. C. The effect of air-hardening and tempering treatments on the mechanical-strength properties follow the same lines as the quench-hardening and tempering treatments described already. The author has described previously[7] the air-hardening properties of an alloy cast iron containing nickel, manganese and chromium of the following complete analysis:—

Total carbon, per cent.	3.49
Graphite, per cent.	2.76
Comb. carbon, per cent.	0.73
Silicon, per cent.	2.80
Manganese, per cent.	2.26
Nickel, per cent.	1.04
Chromium, per cent.	0.57

Hardening and Tempering and Internal Stress

Experimental work on the influence of hardening and tempering on internal-stress conditions has been carried out by the aid of ring specimens.[3] When cutting gaps in test rings of this form, it is noticed that the cut ring may show a tendency to open or close. By cutting the gap in the ring while it is held in a clamp, the gap as cut can be measured. The difference between this gap measurement and the free gap measurement after the release of the clamp indicates the amount of gap movement. The amount

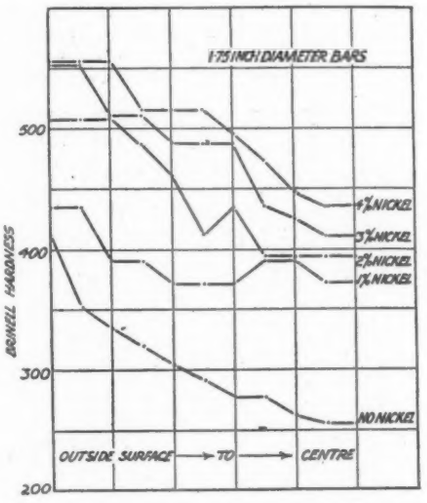


FIG. 13.—EFFECT OF VARYING NICKEL CONTENTS ON DEPTH OF HARDENING ON 1.75-IN. DIA. BARS.

of gap movement recorded in inches, a positive gap movement indicating opening and a negative gap movement indicating closing, enables a comparative study of the changes in internal stress conditions to be made.

In a comparative study of these conditions in the samples whose compositions are recorded in Table I, all the specimens in the " as-cast " conditions showed positive gap movements and, while the variation in magnitude of the gap movements was irregular, the initial presence of internal stresses was indicated. In the hardened condition, all the specimens, without exception, showed negative gap movements and, while this negative movement or closing of the gap varied in magnitude, the movement was of a substantial

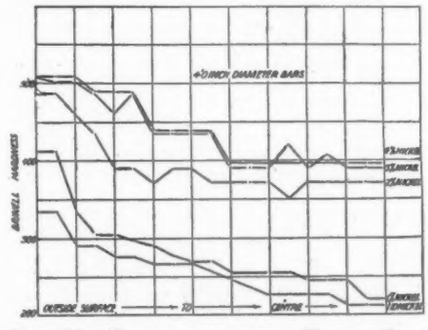


FIG. 14.—EFFECT OF VARYING NICKEL CONTENTS ON DEPTH OF HARDENING IN 4-IN. DIA. BARS.

order and indicated a complete reversal of the condition of internal stress from that present in the material in the " as-cast " condition.

In the tempered specimens, while the individual variations recorded were still irregular, in all cases up to a tempering temperature of 450 deg. C. the gap movements were negative in sign. With a tempering temperature of 600 deg. C. all the gap movements reverted to the

positive sign, that is, in gap opening, but lower in magnitude than those of the material in the original " as-cast " condition. Numerous additional experiments appear to confirm that the hardening operation is accompanied by a complete reversal of the internal stress condition as made manifest by the gap movement in slitted rings and tempering at successively higher temperatures is accompanied by a progressive recovery until the characteristics of the " as-cast " condition are obtained. Some of the actual results obtained on the specimens referred to are illustrated in Fig. 16.

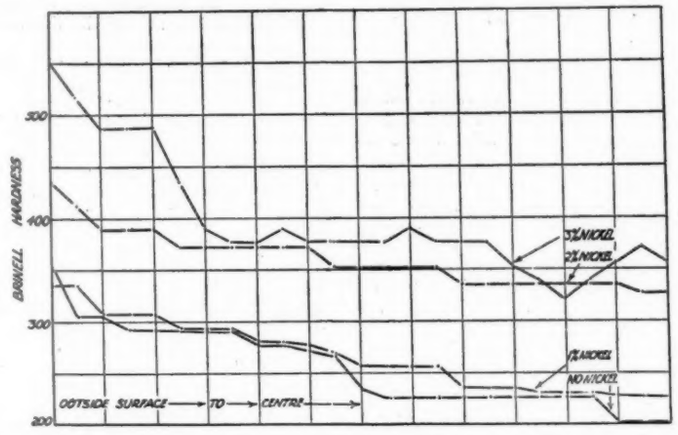


FIG. 15.—EFFECT OF VARYING NICKEL CONTENTS ON DEPTH OF HARDENING IN 5.5-IN. DIA. BARS.

It will be appreciated at once that they indicate the existence of something in the nature of a critical tempering temperature at which the internal stress condition, as revealed by the gap movement, is zero. By replotting the gap movements in relation to tempering temperatures, as in Fig. 16, it would appear that this critical tempering temperature for these specimens lies within the range of 500 to 570 deg. C. This observation is one of obvious importance in the practical heat-treatment of cast iron by hardening and tempering.

However, its importance does not quite end there. Further experiments on specimens of the same material subjected to a stabilising treatment at 550 deg. C. for 20 min. and an annealing treatment at 900 deg. C. for 50 min., followed by slow cooling, failed to remove the internal stress (gap movement) as present in the original " as-cast " material. In fact, these treatments appeared to result in an increase in the gap movement and consequently in the internal stress. From these results, it is almost impossible to resist the conclusion that these stabilising and annealing treatments actually increased the internal-stress condition and certainly the only way of obtaining a gap movement of nil was by quench hardening and tempering at the critical tempering temperature. It is also of interest to record that the hardening and tempering of these specimens after submission to the stabilising and annealing treatments brought about variations in internal stress characteristics of a similar nature to those recorded for the treatment of the " as-cast " specimens.

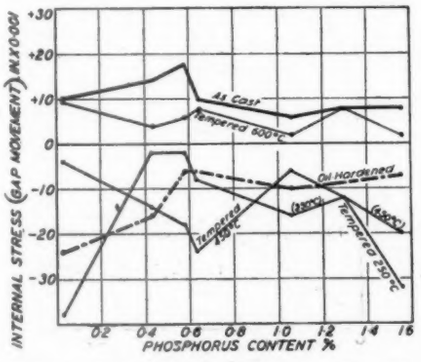


FIG. 16.—GAP MOVEMENT (INTERNAL STRESS), AS CAST, HARDENED AND TEMPERED.

In presenting this study of the heat-treatment of cast iron by hardening and tempering, the author has endeavoured to review the results of investigations which have accrued during the past few years. Those who are interested in the development of cast iron as a constructional material, will derive no small sense of satisfaction from the knowledge that it responds to heat-treatment methods and that by such means, modifications in properties of utilitarian value can be obtained. In the case of other metals and alloys, heat-treatment of this nature has proved to be a facility which has played a very big part in their extended development and it may play a similar part in the case of cast iron.

The Institute of Vitreous Enamellers

NEW MEMBERS ELECTED

At a council meeting of The Institute of Vitreous Enamellers held in Birmingham recently, the following were elected to the various grades of membership.

As Subscribing Firm Members.

John Summers & Sons, Limited, Hawarden Bridge Steelworks, Shotton, Chester; Courtin & Warner, Limited, Worcester Street, Southwark Street, Borough, S.E.1.

As Members.

Lionel James Truss, L. J. Truss, Limited, Holywell Mill, Ashby-de-la-Zouch, Leicestershire.

Estimation of Cobalt and Manganese

A new volumetric method for the potentiometric estimation of cobalt in an ammoniacal ammonium-citrate solution by oxidation with potassium ferricyanide is described by P. DICKENS and G. MAASSEN in the " Archiv für das Eisenhüttenwesen." Titrations can be performed in air, and the usual difficulties encountered when translating a laboratory process to works practice have been avoided. The presence of nickel in any concentrations does not affect the accuracy of cobalt estimation. Manganese can be similarly estimated, and in the presence of both cobalt and manganese the total of the two elements is obtained. The Paper contains full details of the analytical procedure.

American Foundrymen's Association

ELECTION OF NEW OFFICERS

MR. JAMES L. WICK, JUN., President and general manager, Falcon Bronze Company, Youngstown, O., was elected President of the American Foundrymen's Association at the annual business meeting on May 7. This honour comes to Mr. Wick after a long career of distinguished service to the foundry industry and in the affairs of the American Foundrymen's Association. For many years he has been active in the cost work of the Association and has taken an active part in the affairs of the Non-Ferrous Division. Prior to his election to the presidency, he was Vice-President and chairman of the Divisional Activities Correlation Committee. Born in Youngstown, O., in 1883, Mr. Wick's career has been centred in that city. He attended Rayen school there and received his higher education at Massachusetts Institute of Technology, from which he was graduated with a Bachelor of Science Degree in Mechanical Engineering. Following graduation, he served as assistant to the general master mechanic, Youngstown Sheet & Tube Company, Youngstown, in 1906 and 1907 and as assistant to the chief engineer in 1907 and 1908. He resigned that position to serve as general manager, secretary-treasurer, to the Crystal Ice & Storage Company, Youngstown, with which he was associated until 1918. In that year he returned to the Youngstown Sheet & Tube Company, and the following year accepted a position as secretary and assistant general manager with the Falcon Bronze Company. He became Vice-President and general manager in 1925 and was elected to his present position in 1929.

MR. HYMAN BORNSTEIN, director, Testing and Research Laboratories, Deere & Company, Moline, Ill., was elected Vice-President of the Association. Mr. Bornstein has served at various times as chairman of the Committee on Grey Iron Castings, and is a member of the Committee on Specifications for Malleable Castings, etc. He also served as a director of the A.F.A. from 1932 to 1935. Mr. Bornstein is a leading authority on cast iron. Born in Chicago in 1891, he attended Armour Institute of Technology from which he was graduated with a Bachelor of Science Degree in Chemical Engineering in 1911. After serving as chemist for the Union Pacific railway and later for Swift & Company, Chicago, he held the position of chemist for the City of Chicago. He resigned that position to become a captain in the Ordnance Department at the outbreak of the world war, following which he became associated with Deere & Company.

MR. DAN M. AVEY, editor of " The Foundry," who has just completed two successful terms as President, was elected a director of the American Foundrymen's Association. This is his second term as a director, his first term being 1931 until his election to the Vice-Presidency in 1933. Mr. Avey is joined on the Board by Mr. Carl C. Gibbs, Mr. Marshall Post, Mr. James R. Allan and Mr. Lester N. Shannon.

Publication Received

Stock Exchanges (London & Provincial) Ten-Year Record of Prices and Dividends. Published by Fredc. C. Mathieson & Sons, 16, Copthall Avenue, London, E.C.2. Price 20s.

Now that business is a little more brisk in the foundry industry this work will have a much greater interest than in previous years. The particular features of the book are the ease of reference; the utility to the super tax payer and the pointers it offers to the ordinary investor. There are a few rather striking omissions, such as General Refractories, Limited, and Qualcast, Limited.

Behaviour of Five Cast Irons in Relation to Creep and Growth at Elevated Temperatures

By H. J. TAPSELL, A.C.G.I., M. L. BECKER, Ph.D., B.Met., and C. G. CONWAY, B.Sc. (National Physical Laboratory)

(*Continued from page* 385.)

Effect of Heat-Treatment on the Properties of Ordinary and Nickel-Chromium Cast Irons

The growth of the ordinary and nickel-chromium cast irons in the as-cast condition is too great between 450 deg. C. and 538 deg. C. to warrant their use in steam-plant components where distortion of appreciable magnitude is not permissible. For certain reasons, based on the shape of the growth curves and the knowledge that much of the growth may be accounted for by the graphitisation of the pearlite, it was considered possible that a heat-treatment at a temperature higher than 538 deg. C. might carry the irons over the early stages of growth and result in a reduction of the growth in subsequent heating at 538 deg. C.

Preliminary tests were carried out on both irons to determine the period of annealing required to effect the structural changes. Specimens were examined microscopically after two days and five days at 600 deg. C. and after one day and five days at 650 deg. C. It was found that the ordinary iron responded to treatment much more readily than did the nickel-chromium iron. In two days at 600 deg. C., the ordinary iron showed definite signs of change, whilst after five days most of the pearlite had graphitised and that remaining had become spheroidised. In the same period the nickel-chromium iron had not been appreciably affected. At 650 deg. C. the breakdown occurred more rapidly. For the ordinary iron five days sufficed to graphitise all the cementite, apart possibly from a certain amount associated with the phosphide eutectic, whilst for the nickel-chromium iron some of the cementite had been graphitised, although a considerable quantity remained in the spheroidised form.

For the actual growth and creep tests two specimens of each material were first heated at 600 deg. C. for five days, the growth during heat-treatment being measured. The average total growth of the ordinary iron specimens after five days was 0.0063 in. per in., and that of the nickel-chromium iron 0.0028 in. per in. The temperature was then lowered to 538 deg. C., and one specimen of each iron was stressed to obtain a creep curve, and the other left unloaded to measure the growth. The beneficial results of the heat-treatment are disclosed by the results given in Table X and the curves shown in Figs. 11 and 12. Repeat tests at 538 deg. C. were then made on fresh specimens after heat treatment at 650 deg. C. for five days, the total growth at this temperature being 0.0086 in. per in. for the ordinary iron, and 0.0027 in. per in. for the nickel-chromium iron. The further improvement effected by heat-treatment at 650 deg. C. is shown by the results in Table X and the curves of Figs. 11 and 12.

To determine whether the pretreatment caused appreciable loss in strength of the irons at air temperature, specimens of the two irons, 0.45 in. in dia., were heat-treated at 650 deg. C. for five days, machined to 0.35 in. dia., and then subjected to a tensile test at air temperature. The results of these tests are compared in Table XI with the results obtained for the irons in the as-cast condition.

TABLE X.—*Growth and Creep of Ordinary and Nickel-Chromium Cast Irons at 538 deg. C. after Heat Treatment at 600 deg. C. and 650 deg. C.*

Material.	Condition.	Stress. Tons per sq. in.	Final strain at 40 days. Per cent.	Rate of strain at 40 days. In. per in. per hr.
Ordinary cast iron ..	As-received	Growth test	0.73	0.00000329
	Heat-treated for 5 days at 600 deg. C.	,,	0.13_5	0.00000050
	Heat-treated for 5 days at 650 deg. C.	,,	0.02_8	0.00000004
	As received	$\frac{3}{4}$	2.01	0.00000916
	Heat-treated for 5 days at 600 deg. C.	$\frac{3}{4}$	0.34	0.00000229
	Heat-treated for 5 days at 650 deg. C.	1	0.23_8	0.00000167
Nickel-chromium cast iron	As-received	Growth test	0.27	0.00000146
	Heat-treated for 5 days at 600 deg. C.	,,	0.07	0.00000025
	Heat-treated for 5 days at 650 deg. C.	,,	0.01_9	0.00000008
	As-received	1	0.86	0.00000617
	Heat-treated for 5 days at 600 deg. C.	1	0.32	0.00000271
	Heat-treated for 5 days at 650 deg. C.	1	0.07_8	0.00000017

The heat-treatment at 650 deg. C. has produced a decided lowering of the strength of the ordinary iron, but has had far less effect in the case of the nickel-chromium iron. The results are in agreement with those of other investigators who have previously shown that such annealing treatments cause less reduction in tensile strength of cast irons containing chromium than of ordinary irons.

No tests have been made to determine the effect of heat-treatment on the creep and growth at 450 deg. C., but it is probable that such treatment would be as beneficial in its effect at 450 deg. C. as at 538 deg. C.

Comparative Behaviour of the High-Alloy Iron at 850 deg. C.

In view of the fact that the Silal, Nicrosilal and Niresist irons have been developed chiefly for use at relatively high temperatures, some comparative creep and growth tests have been made on these irons at 850 deg. C. The creep and growth specimens used were each 0.30 in. in dia. and of 2-in. gauge length. The results of the tests are given in Table XII.

It is evident that the Nicrosilal cast iron is superior to the other cast irons as regards growth at 850 deg. C. Judging from the results of the tests at 1 ton per sq. in., the Nicrosilal iron appears to be definitely superior to the Niresist as regards resistance to creep at 850 deg. C.

It may be noted that scaling and oxidation below the surface cause appreciable wastage, particularly in the case of Niresist, and it is probable that this affects the life under stress of the relatively small specimens used. For larger specimens the wastage factor would presumably be less pronounced.

At 850 deg. C. a thin protective scale appears to be produced on Silal, but after 15 days the structure is not greatly affected, apart from a possible slight thickening of the graphite flakes.

The scale produced on Nicrosilal seems also to behave in a protective manner, and the wastage is not excessive after 40 days at 850 deg. C. On the other hand, a certain amount of decarburisation occurs beneath the scale, whilst in the particular sample examined grey-coloured crystals were observed in the metal some distance below the surface. The austenite appears to remain unchanged during service at 850 deg. C.

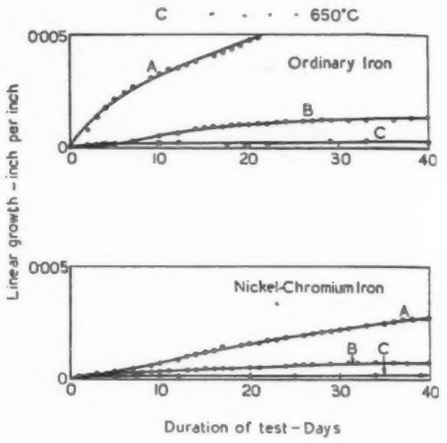


FIG. 11.—EFFECT OF HEAT-TREATMENT ON LINEAR GROWTH OF CAST IRONS AT 538 DEG. C.

A, as received; B, after 5 days at 600 deg. C.; C, after 5 days at 650 deg. C.

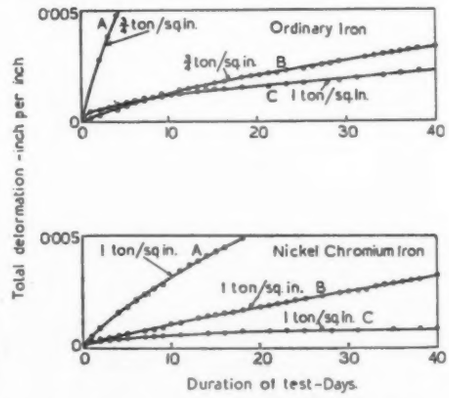


FIG. 12.—EFFECT OF HEAT-TREATMENT ON DEFORMATION UNDER TENSILE STRESS OF CAST IRONS AT 538 DEG. C.

A, as received; B, after 5 days' growth at 600 deg. C.; C, after 5 days' growth at 650 deg. C.

(*Continued on page* 408.)

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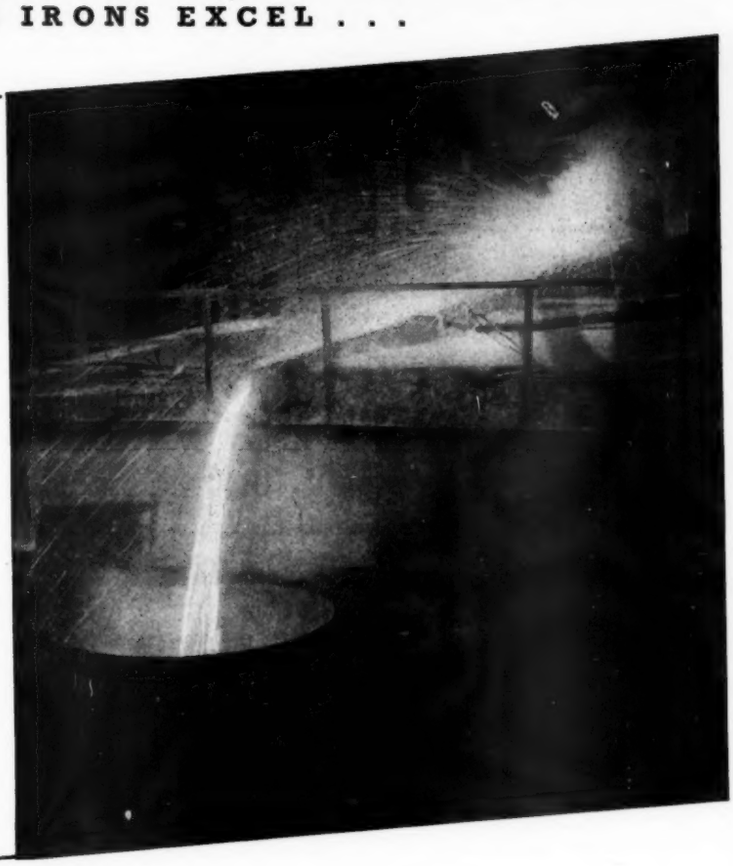

LOW PHOSPHORUS

It is well known to practical foundrymen that a high phosphorus content promotes fluidity—but metal high in phosphorus is slow in setting, allowing gases to work through the metal and causing porosity and sponginess.

For good castings for valves, pumps, etc., phosphorus in the casting should not exceed 0·3%.

The phosphorus in Workington Irons is such that there is an ample margin to allow mixture with irons of higher phosphorus content, whilst still keeping the phosphorus in the casting down to the desirable figure.

Special low sulphur and phosphorus iron is available with S. & P. down to 0.02% max.

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WORKINGTON West Coast Hematite PIG IRONS

W 24.

After the specimen of Niresist cast iron had been tested for growth at 850 deg. C. for 42 days, it was found to have a very hard skin, of depth about 0.05 in. The skin or scale adhered quite firmly, and was not readily detached except by hammering.

The microstructure at the junction of the skin and body of the material shows that the skin consists of material which has been partly oxidised in a uniform manner, that is, the amount of free metal in the skin is the same throughout its thickness. A thin zone, apparently containing a high proportion of oxide, is found at the junction of the oxidised and unoxidised material, whilst the reddish colour observed within the zone suggests the presence of small quantities of metallic copper, possibly the result of differential oxidation. A small portion of the skin was detached from part of the specimen by hammering it on an anvil. Although the quantity thus obtained was insufficient for a complete analysis, it was found that the portion soluble in warm hydrochloric acid contained 21 per cent. of nickel and 9 per cent. of copper; and on dissolving in hot hydrochloric acid, hydrogen was evolved equivalent to about 24 per cent. of free metal calculated as nickel. This indicates that roughly one-quarter to one-third of the skin consists of free metal.

The main structural characteristics of the body of the material of the Niresist cast iron have not been altered by exposure at 850 deg. C., but the large number of specks suggests that a small amount of some constituent, possibly graphite, has developed in the austenitic solid solution.

TABLE XI.—*Effect of Heat Treatment at 650 deg. C. on the Tensile Properties at Air Temperature.*

Material.	Condition.	Ultimate stress. Tons per sq. in.		Approximate elongation on gauge length. $L = 4\sqrt{\text{area}}$. Per cent.
		Individual values.	Average value.	
Ordinary iron ..	Heat-treated for 5 days at 650 deg. C.	9.8	10.0	0.5
		10.3		0.5
		14.6		0.5
	As-cast	15.8	15.3	0.5
		15.4		0.5
Nickel-chromium iron	Heat-treated for 5 days at 650 deg. C.	12.6	12.0	0.5
		11.4		0.5
	As-cast	14.3	13.3	0.5
		12.3		0.5

Conclusions

The results of the investigation show that the ordinary and nickel-chromium cast irons retain useful strength at temperatures up to 538 deg. C. (1,000 deg. Fah.), but that in the condition as-cast the rates of growth and creep would be greater than those generally considered permissible for steam plant operating at this degree of superheat. The creep and growth properties of both irons may, however, be considerably improved by heat treatment below the critical temperature for a suitable period, say five days at 650 deg. C. The growth which occurs at superheated steam temperatures appears to be largely due to the graphitisation of the pearlite cementite, and the function of the heat treatment is to bring about most of this decomposition before the material is finally machined and put into service.

The resistance to creep and growth of Silal cast iron at 538 deg. C. is much greater than that for ordinary and nickel-chromium irons, and is, in fact, of the same order as for these irons in the heat-treated condition referred to above. In view of the low combined carbon content of the Silal, this is not surprising, and the effect of heat treatment at about 650 deg. C. has not been investigated, as little improvement seems likely to be obtained with this iron.

Examination of the austenitic cast iron Nicrosilal indicates that the austenite constituent is unstable at 538 deg. C., at 450 deg. C., and probably at even lower temperatures. The rate and manner of breakdown are influenced to some extent by slight changes in composition, and by heat treatment at a temperature above 1,000 deg. C., but the ultimate result is little affected. The austenite breakdown causes a comparatively rapid growth and creep, and it appears, therefore, that at such temperatures Nicrosilal is unsuitable for service where permanence of dimensions and retention of the austenitic condition are essential.

On the other hand, the austenite constituent of Niresist cast iron is stable at 538 deg. C. and 450 deg. C., and this iron possesses good growth and creep properties at these temperatures. Actually the growth and creep at low stresses appear to be less at 538 deg. C. than at 450 deg. C., and although the reason for this is not clear, it is possibly not unconnected with the more rapid graphitisation and the earlier attainment of a stable state at the higher temperature. In view of experience gained during the research, it seems likely that the growth and creep properties of Niresist might be improved at superheated steam temperatures by giving a preliminary heat treatment, such as has been applied successfully to the ordinary and nickel-chromium irons. In this event the properties at 538 deg. C. and 450 deg. C. might assume the more usual relationship.

TABLE XII.—*Results of Comparative Tests at 850 deg. C.*

Material.	Stress. Tons per sq. in.	Duration of test. Days.	Final strain. Per cent.
			Linear growth.
Silal cast iron	Growth test	15	2.52
Niresist cast iron	,,	42	0.33
Nicrosilal cast iron (1st batch	,,	41	0.05
			Elongation on 2 in. at fracture.
Niresist cast iron	1	1.9 (broken)	0.75
Nicrosilal cast iron (1st batch)	1	4–5 (broken)	1.0
Nicrosilal cast iron (2nd batch)	1	13 (broken)	1.5

In regard to properties at 850 deg. C., it has been shown that the growth of the Nicrosilal cast iron is less than that of the Niresist iron, and much less than that of the Silal iron. As far as resistance to creep at 850 deg. C. is concerned, the results of the single tests at 1 ton per sq. in. indicate that the Nicrosilal, particularly that of the second batch, is superior to the Niresist. A hard layer of partly oxidised metal is formed on the surface of Niresist at 850 deg. C., but it appears that this is less protective against further oxidation of the underlying metal than is the thinner scale formed on Nicrosilal and Silal.

Acknowledgments

The investigation of the properties of cast irons forms part of the current research carried out at the National Physical Laboratory on behalf of the Committee on the Behaviour of Materials at High Temperatures of the Department of Scientific and Industrial Research, to whom the authors are indebted for permission to publish the results. The thanks of the authors are due to Dr. H. J. Gough, M.B.E., F.R.S., Superintendent, Engineering Department, and to Dr. C. H. Desch, F.R.S., Superintendent, Metallurgy Department, National Physical Laboratory, for their interest and encouragement in the work, and to Dr. C. H. M. Jenkins, Metallurgy Department, National Physical Laboratory, for his valuable help and advice.

French Foundrymen's Association

ANNUAL MEETING AT LILLE

The annual meeting of the Association Technique de Fonderie de France is to be held in Lille from June 25 to 28. The following Papers are expected to be presented:—

"New Aluminium Alloys for the Foundry," by G. Cheron.

"Determination of the Hardness of Pellicules of Aluminium," by M. Hache.

"Corrosion and Protection of Cast Aluminium Alloys," by M. Lacombe.

"The Bell Test for Gases from Aluminium," by M. Moreau.

"Heat-Treatment of Cast Iron," by G. Delbart.

"Cast Iron and Slag Reactions as Affected by Churning—Applications to Pig and Cast Iron," by Prof. L. F. C. Giradet.

"Melting High-Duty Irons in the Small Cupola," by G. Henon.

"Influence of Heat-Treatments below the A_1 Point on the Properties of Black-Heart Malleable Cast Iron," by M. Leroyer.

"Fundamental Notions Underlying the Development of Cast Non-Ferrous Alloys in Germany since 1933," by Dr. W. Claus (German Exchange Paper).

"The Standardisation of Methods used for the Determination of Total Carbon," by M. Gevers (Belgian Exchange Paper).

"Resilience and Strength of Cast Iron as revealed by the Loading Curves of the Transverse Test," by G. L. Harbach (British Exchange Paper).

"Influence of Atmospheric Moisture on Dried Moulds and Naturally-Bonded Cores," by B. Holman (Czech Exchange Paper).

"Regeneration, Preparation and Handling of Moulding Sands," by Lester B. Knight (American Exchange Paper).

"Evaluation of High-Duty Cast Iron," by R. P. Lemoin.

Amongst the works to be visited are those of Usines de Marquise (June 25); Etablissements Sculfort-Fockedey, Vautier & Company and the Société Métallurgique de Senelle Mauberge, or the Société des Hauts Fourneaux, Forges et Aciéries de Denain et Anzin (June 26); Compagnie de Fives-Lille; Services de Recherches de l'Institut de Chemie (June 27).

The Annual Banquet, which is to be given by the Northern Ironfounding Employers' Federation, is to be held on the evening of Saturday, June 27. It will be presided over by the Under-Secretary for State for Technical Education. On Sunday, an excursion to the neighbourhood of Cassel has been organised. A special programme for ladies has been prepared, which includes visits to textile and hat factories, museums, etc.

CUMMING'S BLACKINGS ARE THE BEST

Extract from daily report by one of our travellers:—

January 9th, 1936.

Mr. C..... said,

"I shall send on to you every time. Since we adopted your Blacking the skin of our castings has improved by 100 per cent. Our customers were the first to notice it."

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This Week's News in Brief

Trade Talk

SHEFFIELD IRON AND STEEL FOUNDRIES report a steady demand for heavy castings, and light repetition work for builders' merchants.

RENFREW DEAN OF GUILD COURT have granted permission to the Carntyne Steel Castings Company, Limited, to erect a new foundry shop.

MR. FRANCIS LEY, the general manager of Ley's Malleable Castings Company, Limited, Derby, made presentations to long service employees of the firm, at the works canteen, on May 13.

F. W. BRACKETT & COMPANY, LIMITED, Colchester, have received an order from Glasgow Corporation to erect a water screening plant at Dalmarnock power station, at a cost of £7,080.

THOS. W. WARD, LIMITED, of Sheffield, have purchased the Cunard liner "Majestic." The price of the deal is estimated at £115,000. No decision has been reached whether the ship will be broken up for scrap.

A PRESENTATION OF BRONZE MEDALS has been made on behalf of the Cunard-White Star Line to the principal foremen and officials of John Brown & Company, Limited, to commemorate the building of the "Queen Mary."

A FIRE ENGINE constructed from a number of obsolete buses by the city surveyor has been presented to Londonderry Corporation. A saving to the rates of approximately £1,700 has thus been effected, as the new engine only cost £300.

B. & F. CARTER & COMPANY, LIMITED, of Rochdale, Lancs, machine makers, have purchased about half of the extensive Kay Street Works, Bolton, formerly occupied by Dobson & Barlow, Limited, textile machinists and ironfounders.

THE BRITISH ALUMINIUM COMPANY, LIMITED, have opened a branch office and warehouse at Rose Street, Temple, Bristol, 1 (telephone number 21747), under the management of Mr. O. Halliwell. At this warehouse the company will hold stocks of their standard products, *i.e.*, aluminium and its alloys in crude and semi-manufactured forms, including ingots, notched bars, sheets, tubes and sections.

AT THE SPRING SHOW of the Royal Dublin Society the Society's silver medal for new implements was awarded to the Wexford Engineering Company, Limited, for a "Star" semi-broadcast corn sower; Bamfords, Limited, Uttoxeter, for a Bamford G.H. patent self-cleaning grassland harrow and rejuvenator; Melotte Separator Sales Company (1931), Limited, Bristol, for the Melotte model S rustless cream separator; and to Philip Pierce & Company, Limited, Wexford, for a quick lift self-trip wheel rake.

IN THE RECENT Irish Free State Budget a duty of 40 per cent. was placed on the following articles, whether completely or partially manufactured, made wholly or mainly of cast iron:—Pavement gutters and component parts; sewer pipe ventilators; air bricks and air grids; furnace fans and furnace doors, furnace door frames, and furnace bottom grates; angle and other wall brackets on which the arm or one of the arms is not less than 7 in. in length; stands, frames and other supports for lavatory basins, kitchen sinks and similar articles and component parts of any such supports; kerbs for fireplaces; earth rammers, whether imported with or without handles; shoe anvils, including sockets and stands therefor, and foot or hobbing irons; name plates, number plates and indicator plates; firegrates, ranges, stoves other than stoves primarily adapted for use for heating water in connection with hot water circulating systems; mantel registers and component parts, but excluding any such article heated by electricity, gas or oil; chimney pieces, mantelpieces and component parts; pots, pans and kettles of all descriptions suitable for domestic or household use and component parts; glue pots and glue cups; smoothing irons and stands, except irons heated externally by gas, electricity or oil; and safes and strong boxes.

Manufacture of Locomotive Castings

(*Concluded from page* 398.)

tests on the 36 in. centres. In this way nine results were obtained for each temperature, and the averages of these are given in Table I.

TABLE I.—*Effect of Casting Temperature in Mechanical Strength.*

Casting temperature in deg. C.	1330	1320	1280	1250	1220	1180
Average transverse breaking load (cwts.)	34.9	32.3	34.8	34.5	29.7	25.8
Average deflection (in ins.)	1/32	1/32	1/32	2/32	3/32	2/32
Average Brinell hardness	222	218	222	219	222	220

It will be seen that, whereas the deflection and Brinell hardness are barely affected by casting temperature, there is a marked loss of strength in bars cast below 1,250 deg. C. This was confirmed by the increased number of flaws discovered in the bars cast at the low temperatures.

It is concluded that for castings of 1 in. section, temperatures below 1,250 deg. C. are to be avoided in the interest of mechanical strength and soundness. For castings of greater section than 1 in. lower temperatures may be permitted, but sections under 1 in. will require even higher temperatures than 1,250 deg. to ensure the best results.

Co-operation of the practical and technical knowledge in the St. Rollox foundry is a great contribution to the success of the foundry. Work of this kind should always go on, and the machinery made as up to date as possible, but there are always the men upon whose performance of their duties the structure depends.

In conclusion, the author wishes to thank the management for the facilities for giving this Paper, and would also thank the few friends who were responsible for providing the illustrations.

Contracts Open

Leeds, May 23.—Cast-iron pipes, wrought-iron tubes and fittings, iron castings, best merchant iron and mild steel, and other metal goods, for the Gas Department. The Town Clerk (Committee Department), Room No. 57, Civic Hall.

Simla, June 4.—Two 10-ton hand-power breakdown cranes, for the Indian Stores Department. The Department of Overseas Trade. (Reference T.Y. 30,137.)

Stockton, May 29.—Castings; compo. and lead pipe, sheet lead, for the Town Council. The Gas Engineer and Manager, Corporation Gasworks, Thompson Street.

Company Reports

Siemens Bros. & Company, Limited.—Dividend of 6 per cent. on the ordinary shares for 1935.

Platt Bros. & Company (Holdings), Limited.—Half-year's dividend on the 4½ per cent. preference shares.

Atlas Steel Foundry & Engineering Company, Limited.—Interim dividend on the ordinary shares of 5 per cent.

William Asquith, Limited.—Total profit, £27,752; loss brought in, £13,481; available, £14,271; year's dividend on the 8 per cent. preference shares, £10,127, bringing the dividend up to March 31, 1933; carried forward, £4,143 Meeting, May 20.

New Company

(From the Register compiled by Jordan & Sons, Limited, Company Registration Agents, 116 to 118, Chancery Lane, London, W.C.2.)

G. L. Harris, Limited, 40-43, Norfolk Street, Strand, London, W.C.2.—Capital £1,000. Engineers, founders, etc. Directors: G. L. Harris, Nellie G. Caseley, and M. D. Booth.

Personal

MR. A. J. THORNTON, general manager of the Irlam Works, Manchester, of the Lancashire Steel Corporation, Limited, has been appointed manager of Skinningrove Iron Works, in succession to Mr. W. S. B. Bosanquet.

MR. GEORGE FLINT, Glasgow, secretary and accountant of the Larbert Art Metal Company, Limited, and Scottish Enamelling Company, Limited, has been appointed director of studies in the Johannesburg School of Accountancy.

MR. JAMES BROWN, C.B.E., of Scotts Shipbuilding & Engineering Company, Limited, Greenock, has been appointed a director of the general board of the Iron Trades Employers' Insurance Association, in place of Sir John Hunter, K.B.E., who has retired after 35 years' service.

MR. JOHN G. WRIGHTSON, son of Sir Guy Wrightson, chairman of Messrs. Head, Wrightson & Company, Limited, is expected back in London on May 25. For the past seven months, Mr. John Wrightson has been in South Africa superintending important contracts for the supply and maintenance of plant in the gold-mining areas. Further, he has been devoting a considerable proportion of his time in overhauling the selling machinery of his firm in that country.

Wills

WAUGH, T., of the Bellevue Brass Foundry, Edinburgh	£844
WHITE, A., managing director of David Caird, Limited, of Barrow-in-Furness	£22,051
BROWN, F. J., of Luton, formerly managing director of Brown & Green, Limited, ironfounders and engineers...	£4,378
BAKER, HERBERT, of Leamington Spa, founder of Sterling Metals, Limited, Coventry, chairman of Bretts Stamping Company, Limited	£126,094

Obituary

THE DEATH HAS OCCURRED of Mr. James Kennedy Thomson, who was for 53 years associated with The Shotts Iron Company, Limited.

Iron and Steel Production

The British Iron and Steel Federation reports that there were 112 furnaces in blast in Great Britain at the end of April, five having been blown in and two put out of operation during the month. The production of pig-iron in April amounted to 629,800 tons compared with 633,600 tons in March, and 526,300 tons in April, 1935; the month's production included 127,900 tons of hematite, 372,100 tons of basic, 94,800 tons of foundry and 16,700 tons of forge pig-iron. The production of steel ingots and castings in April amounted to 991,500 tons compared with 980,100 tons in March, 1936, and 808,700 tons in April, 1935.

Forthcoming Events

MAY 26.

Institution of Civil Engineers:—Ordinary Meeting; "Recent Developments in Metallurgy and their Influence on Engineering," Paper by M. Eugene Shneider, at 6 p.m.

MAY 27.

Manchester Association of Engineers:—Visit to the works of Mather & Platt, Limited, Park Works, Newton Heath, at 2.30 p.m.

MAY 30, 31 AND JUNE 1.

The Institute of Vitreous Enamellers:—Second Scottish Conference in Glasgow.

JUNE 8-13.

Twelfth International Congress of Acetylene, Oxy-Acetylene Welding and Allied Industries:—To be held in London.

Institute of British Foundrymen

JUNE 9-12.

Annual Conference in Scotland.

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DATE 25th.Feb. 1936.

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HALIFAX.
Yorks.

Dear Sirs,

In reply to your letter of the 13th.instant, we enclose herewith the two negatives of the Foundry Plant you recently installed for us.

We may say that the Plant continues to give satisfaction and we are obtaining the following output:-

Green Sand	-	25 cwts. per hour.
Facing Sand	-	25 " "
Oil Sand.	-	15 " "

The plant is well ahead of our requirements and is running daily.

Yours faithfully,
REAVELL & CO.LTD.

encl.2 negatives.

Raw Material Markets

Current business in the iron and steel markets does not amount to any substantial tonnage. The question of prices for the second half of the year is expected to be settled in the near future, and, until then, markets will inevitably remain quiet. Deliveries to consumers are still on a heavy scale. The output of pig-iron is to be increased by the lighting of another furnace in the Cleveland area during the course of the next week or two.

Pig-Iron

MIDDLESBROUGH.—Deliveries of Cleveland pig-iron against existing contracts have fallen into heavy arrears, but it is hoped that some relief may be given to the situation during the next few weeks by increasing the output. New business is out of the question, and will remain so for a considerable period. Larger tonnages of Midland pig-iron have been taken for distribution to Cleveland and Scottish consumers. For deliveries up to the end of June the official prices of No. 3 G.M.B. are 70s. per ton in the Middlesbrough and Falkirk areas, 72s. on the North-East Coast, and 73s. on Clydeside. From July 1 these prices will be increased by 5s. per ton.

The demand for East Coast hematite remains considerably in excess of the supply, and consumers are pressing the makers for heavy deliveries. Users are naturally anxious to acquire stocks in view of the higher prices which will rule in the near future. An additional furnace has been re-lit on the West Coast, but its output is fully disposed of under existing contracts. Values, it is generally thought, will be raised by 5s. per ton in July and, meanwhile, deliveries are charged on the basis of No. 1 East Coast hematite at 77s. per ton delivered North-East Coast or Scotland.

LANCASHIRE.—Little new business has been transacted during the past week, but deliveries against existing contracts are heavy, users desiring to accumulate stocks before the higher prices come into operation. The light-castings foundries, heavy electrical engineering and machine-tool works, jobbing foundries and paper-making machinery factories have all been taking up large tonnages of pig-iron. Textile machinists are, however, only quietly employed, and their requirements are considerably below the normal level. Quotations for pig-iron are firm, with Derbyshire, Staffordshire and Lancashire brands of No. 3 foundry for delivery in the Lancashire price zone on the basis of 78s. per ton for delivery up to June 30, with Northants at 76s. 6d., and prices for delivery on and after July 1 at 5s. per ton more in each case. Scottish iron is quoted at around 89s. per ton, East Coast hematite at from 84s. 6d. to 85s., and West Coast iron at about 85s. 6d., all delivered in the Manchester district.

MIDLANDS.—Consumers of Midland brands of foundry iron, particularly in the light-castings trade, are calling for heavy deliveries. In contracts where delivery is to be made after the end of June 5s. per ton premium is required. Present Association minimum quotations, delivered Birmingham and Black Country stations, are 72s. 6d. for Northants No. 3 and 75s. for Derbyshire, Lincolnshire and North Staffordshire No. 3. Forge pig-iron is in short supply, and has a heavy demand. For the ironworks this class of iron is quoted 5s. per ton below No. 3 foundry, but for the ironfoundries only 3s. reduction is allowed. The heavy engineering and jobbing foundries are heavy consumers of special pig-iron, and supplies are being obtained from various areas. Scottish No. 3 and other low-phosphorus irons are quoted between 92s. 6d. and 100s., while medium-phosphorus is from 80s. to 87s. 6d. Refined iron receives numerous inquiries, and prices range from £6 10s. to £7 15s. delivered this district. Hematite iron remains in heavy demand, and many users are having to wait for supplies. Prices up to the end of July are £4 8s. 6d. for West Coast mixed numbers, £4 7s. 6d. for East Coast No. 3, and £4 7s. for Welsh mixed numbers, delivered Midland stations. Prices for delivery after July have not been fixed, and all deliveries falling due after July 30 are to be paid for at the prices then ruling.

GLASGOW.—Consumption of pig-iron is on a good scale in this district, and deliveries of hematite and basic are heavy. An increased tonnage of basic iron has been acquired from India, and a shipment of 2,000 tons of foundry iron has also arrived from the same country. The official minimum price of No. 3 foundry is unchanged at 79s. f.o.t. furnaces, with 2s. 6d. extra for No. 1. No. 3 Cleveland iron remains at 70s. f.o.t. Falkirk and 73s. f.o.t. Glasgow. Supplies of this iron are still unobtainable. No change has been made in the basis rate of 77s. for East Coast, West Coast and Scottish hematite, but higher figures have been obtained. British and Indian basic is quoted at 72s. 6d., less 5s. rebate, delivered steelworks. This iron, however, is in very short supply.

Coke

Prices are firmly maintained in the foundry-coke market, and there is every prospect of their remaining so throughout the summer months. For delivery in Birmingham and district, best Durham coke is quoted from 41s. 6d. to 43s., and Welsh coke varies from about 39s. up to 50s. per ton.

Steel

The activity in the steel market shows no signs of relaxing, and practically all departments are working at capacity, states the official report of the London Iron and Steel Exchange. The heavy-steel trades can see their way to continue their present rate of production until late in the year, and are not anxious to accept new business for delivery before July. Although the volume of new business is less than it was a month or two ago, it is due principally to the reluctance of the manufacturers to incur fresh commitments. The situation in the semi-finished steel department has become somewhat easier as a result of the importations of Continental material. All the British producing works are operating at capacity, and in many cases are in arrears with deliveries. In the finished-steel market buyers are not finding it easy to place orders, as, in view of the expected changes in prices, the manufacturers are not anxious to sell for delivery beyond July. Many consuming concerns, however, have covered their requirements for some time ahead. In these conditions, new business in finished steel has been quiet, but heavy deliveries have been made to the consuming industries.

Scrap

Heavy melting steel remains at 57s. 6d. per ton delivered works on the Cleveland market, and buying is very keen. Supplies of machinery metal and ordinary heavy foundry cast iron are more easily procured at 65s. and 62s. 6d. respectively. All qualities of scrap receive numerous inquiries on the Midland market. Heavy steel in furnace sizes is at 52s. 6d. to 55s., while 52s. 6d. is offered for mixed iron and steel. Heavy, unsheared wrought-iron remains at 67s. 6d. to 70s. Heavy machinery cast-iron scrap in handy sizes is at 70s., good heavy at 65s., and clean light at 52s. 6d. to 55s. It remains difficult to obtain adequate supplies of short, heavy steel, suitable for foundry purposes, and 70s. per ton delivered works for good parcels is still being offered. All descriptions of scrap are plentiful on the Scottish market, home supplies being considerably augmented by imported material. Heavy, mild-steel, melting scrap is unchanged at 57s. 6d., while heavy basic, or heavy iron and steel scrap mixed, remain at 52s. 6d. Heavy machinery cast-iron scrap is slightly easier at around 71s. to 71s. 3d., for pieces not exceeding 1 cwt., while for ordinary cast-iron scrap, to the same specification, 66s. 6d. to 67s. 6d. per ton, delivered f.o.t. consumers' works, is quoted.

Metals

Copper.—This market has ruled quiet during the week, and buying has not amounted to any substantial tonnage. Publication of the April statistics had a stimulating effect on the market, but this was not maintained. Conditions in the United States, also, are dull. The April figures are fairly satisfactory, the net showing being a reduction of about 12,000 tons in world stocks of refined copper over the month. This reduction was divided as to 4,700 tons in the United States and 7,300 tons elsewhere.

Daily market prices :—

Cash.—Thursday, £36 13s. 9d. to £36 15s.; Friday, £36 16s. 3d to £36 17s. 6d.; Monday, £36 12s. 6d. to £36 15s.; Tuesday, £36 11s. 3d. to £36 12s. 6d.; Wednesday, £36 5s. to £36 6s. 3d.

Three Months.—Thursday, £37 to £37 1s. 3d.; Friday, £37 2s. 6d. to £37 3s. 9d.; Monday, £36 18s. 9d. to £37; Tuesday, £36 17s. 6d. to £36 18s. 9d.; Wednesday, £36 11s. 3d. to £36 12s. 6d.

Tin.—Steady conditions have prevailed in this market recently and, while buying has not been of a considerable volume, consumption has been well maintained. In the United States the tinplate and automobile industries are heavy users of tin. The International Tin Committee, at their meeting on May 26, will be faced with the problem of the extent of the United States restocking movement. Total consumption in industry in the latter country during the first quarter of the year was 14,600 tons, against 15,620 tons in the corresponding period of last year. The Bolivian delegates to the committee are still of the opinion that they will be able to make good their deficiency, but it is generally anticipated that an upward revision of quotas will be made.

Metal Exchange quotations were as follow :—

Cash.—Thursday, £204 10s. to £205; Friday, £205 7s. 6d. to £205 10s.; Monday, £202 15s. to £203 5s.; Tuesday, £200 5s. to £200 10s.; Wednesday, £198 5s. to £198 10s.

Three Months.—Thursday, £198 10s. to £198 15s.; Friday, £199 7s. 6d. to £199 10s.; Monday, £197 15s. to £198 5s.; Tuesday, £195 10s. to £195 15s.; Wednesday, £193 15s. to £194 5s.

Spelter.—Conditions in this market are very colourless, and buying interest only concerns very small tonnages, except in the case of the brass-making concerns, which are taking up supplies of high-grade zinc on a good scale. The United States market is also quiet and featureless. No developments have been announced concerning the re-establishment of the International Zinc Cartel, and it is now thought that it will, at the least, be late autumn before any definite move is made.

Official quotations were as follow :—

Ordinary. — Thursday, £14 10s.; Friday, £14 16s. 3d.; Monday, £14 13s. 9d.; Tuesday, £14 10s.; Wednesday, £14 7s. 6d.

Lead.—Although consumption is reported to have been maintained satisfactorily, conditions are dull. The undertone of the market remains quite sound. In the United States the demand remains about equal to the supply, while quotations are steady.

Day-to-day quotations :—

Soft Foreign (Prompt).—Thursday, £15 8s. 9d.; Friday, £15 10s.; Monday, £15 10s.; Tuesday, £15 10s.; Wednesday, £15 7s. 6d.

Patent Specifications Accepted

The following list of Patent Specifications accepted has been taken from the "Official Journal (Patents)." Printed copies of the full Specifications are obtainable from the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1s. each. The numbers given are those under which the Specifications will be printed and abridged, and all subsequent proceedings will be taken.

440,788. KRUPP AKT.-GES., F. Corrosion-resistant alloys.

440,833. GALES, SIR R. R. Fishplates for railway rail joints.

440,896. RICHARDS, F., and BRITISH (GUEST KEEN BALDWINS) IRON & STEEL COMPANY, LIMITED. Means for securing rails to metal sleepers.

440,984. BRITISH THOMSON-HOUSTON COMPANY, LIMITED. Methods of and alloy for deoxidising silicon steel.

440,997. DORMAN, LONG & COMPANY, LIMITED, and LEWIS, J. S. Method of and apparatus for treating furnace slag for the production of foamed and granulated slag.

441,126. GILBERT, W. V. Processes for treating metals and alloys.

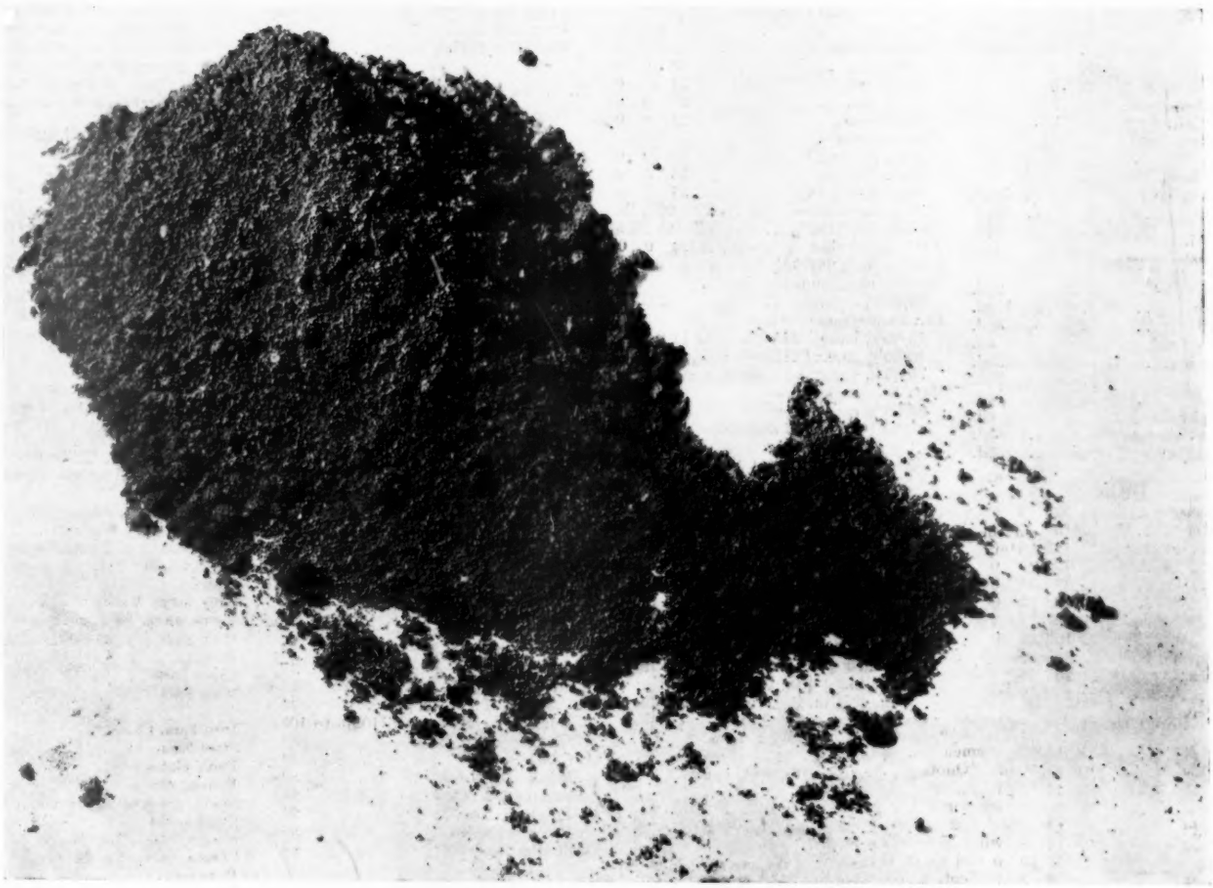
441,243. BOSCH AKT.-GES., R. Permanent magnets and alloys for making the same.

441,252. WEIMAR, W. Process and apparatus for utilising worn steel wire cables.

441,313. DAVIES, S. K., and BRUNTON, J. D. Wire ropes.

441,329. SHORTER, A. E., and PATENT GEAR & METAL HARDENING COMPANY, LIMITED. Apparatus for hardening metal surfaces.

TOR ROCK SAND



It is now possible to obtain from a deposit in the Midlands, a moulding sand possessing all the excellent characteristics of the Scottish Rock sands. This sand we have called Tor Rock Sand. It is well bonded, coarse in grain, and highly permeable.

The advantage this sand offers to iron founders in the Midlands and the South is obvious. Railway rates, which represent a high proportion of the cost of moulding sand when delivered are reduced considerably. Please write for full particulars and samples.

CHEMICAL ANALYSIS

Silica	86·8 %
Ferric Oxide	1·43%
Alumina	7·6 %
Lime	·22%
Magnesia	·18%
Titanic Oxide	·18%
Alkalies	1·8 %
Loss on ignition	1·6 %

MECHANICAL ANALYSIS

Very Coarse Sand (+ 1 mm)	16·5%
Coarse Sand (+·5 mm−1 mm)	16·0%
Medium Sand (+·25 mm−·5 mm)	11·0%
Fine Sand (+ ·1 mm−·25 mm)	30·0%
Silt Grade (+ ·01 mm−·1 mm)	7·0%
Clay Grade (−·01 mm)	19·5%

GENERAL REFRACTORIES Ltd.,

Genefax House, Sheffield.

Telephone: Sheffield 31113 (6 lines). Telegrams: "Genefax, Sheffield."

London Office:
Russell House,
Adelphi, W.C.2.
Telephone: Temple Bar 7361.
Telegrams:
"Genefax, Rand-London."

Scottish Office:
156, St. Vincent St.,
Glasgow.
Telephone: 5250
Telegrams:
"Genefax, Glasgow."

South Wales Office:
11, Wind St.,
Swansea.
Telephone: 3680.
Telegrams:
"Genefax, Swansea."

MANUFACTURERS OF HEAT RESISTING AND HEAT INSULATING MATERIALS OF EVERY DESCRIPTION.

RAW MATERIALS—PRICE LIST

(Wednesday, May 20, 1936)

COPPER

	£ s. d.
Standard cash	36 5 0
Three months	36 11 3
Electrolytic	40 10 0
Tough	39 0 0
Best selected	39 15 0
Sheets	70 0 0
India	50 0 0
Wire bars	41 2 6
Ingot bars	41 2 6
H.C. wire rods	44 15 0
Off. av. cash, April	37 0 2½
Do., 3 mths., April	37 5 11½
Do., Sttlmnt., April	37 0 1½
Do., Electro, April	41 6 8½
Do., B.S., April	40 15 0
Do., wire bars, April	41 10 9
Solid drawn tubes	10½d.
Brazed tubes	10½d.
Wire	6½d.

BRASS

Solid drawn tubes	9¾d.
Brazed tubes	11½d.
Rods, drawn	8¾d.
Rods, extd. or rlld.	8d.
Sheets to 10 w.g.	7¾d.
Wire	7¾d.
Rolled metal	7½d.
Yellow metal rods	5d.
Do. 4 × 4 Squares	5½d.
Do. 4 × 3 Sheets	5½d.

TIN

	£ s. d.
Standard cash	198 5 0
Three months	193 15 0
English	198 0 0
Bars	199 5 0
Straits	199 15 0
Australian (nom.)	198 5 0
Eastern	201 2 6
Banca	199 10 0
ff av. cash, April	209 9 0¾
Do., 3 mths., April	203 16 3
Do., Sttlmt., April	209 8 0

SPELTER

	£ s. d.
Ordinary	14 7 6
Remelted	13 10 0
Hard	11 5 0
Electro 99.9	16 10 0
English	15 7 6
India	12 15 0
Zinc dust	19 10 0
Zinc ashes	4 5 0
Off. aver., April	15 5 1¾
Aver. spot, April	15 3 7½

LEAD

	£ s. d.
Soft foreign ppt.	15 7 6
Empire (nom.)	16 5 0
English	17 10 0
Off. average, April	16 3 3¾
Average spot, April	16 1 11¼

ALUMINIUM

Ingots	£100 to £105
Wire	1/3 to 1/4 lb.
Sheet and foil	1/2 to 1/4 lb.

ZINC SHEETS, &c.

Zinc sheets, English	24 10 0 to 25 0 0
Do., V.M. ex-whse.	24 10 0 to 25 0 0
Rods	27 0 0

ANTIMONY

English	66 10 0 to 67 10 0
Chinese, ex-whse.	55 0 0
Crude, c.i.f.	27 10 0

QUICKSILVER

Quicksilver	11 15 0 to 12 7 6

FERRO-ALLOYS AND STEEL-MAKING METALS

Ferro-silicon—	
25%	8 17 6
45/50%	12 15 0
75%	17 17 6
Ferro-vanadium—	
35/50%	12/8 lb. Va.
Ferro-molybdenum—	
70/75% carbon-free	4/6 lb. Mo.
Ferro-titanium—	
20/25% carbon-free	9d. lb.
Ferro-phosphorus, 20/25%	£21 0 0 to £22 0 0
Ferro-tungsten—	
80/85%	3/- lb.
Tungsten metal powder—	
98/99%	3/3 lb.
Ferro-chrome—	
2/4% car.	33 0 0
4/6% car.	21 15 0
6/8% car.	21 0 0
8/10% car.	21 0 0
Ferro-chrome—	
Max. 2% car.	33 10 0
Max. 1% car.	36 5 0
Max. 0.70% car.	37 5 0
70% carbon-free	9½d. lb.
Nickel—99.5/100%	£200 to £205
"F" nickel shot	£184 0 0
Ferro-cobalt, 98/99%	6/3 to 6/9 lb.
Metallic chromium—	
96/98%	2/5 lb.
Ferro-manganese (net)—	
76/80% loose	£11 5 0 to 11 15 0
76/80% packed	£12 5 0 to 12 15 0
76/80% export	(nom.) £10 5 0
Metallic manganese—	
94/96% carbon-free	1/3 lb.

Per ton unless otherwise stated, basis 2-ton lots.

HIGH-SPEED TOOL STEEL

Finished bars, 14% tungsten	2s. 0d.
Finished bars, 18% tungsten	2s. 9d.

Per lb. net, d/d buyers' works.

Extras—	
Rounds and squares, 3 in. and over	4d. lb.
Rounds and squares, under ½ in. to ¼ in.	3d. lb.
Do., under ¼ in. to $\frac{1}{16}$ in.	1/- lb.
Flats, ½ in. × ¼ in. to under 1 in. × ⅛ in.	3d. lb.
Do., under ⅛ in. × ¼ in.	1/- lb.
Bevels of approved sizes and sections	6d. lb.

Bars cut to length, 10% extra.

SCRAP

	£ s. d.	£ s. d.
South Wales—		
Heavy steel	3 5 0	to 3 6 0
Mixed iron and steel	3 0 0	to 3 1 6
Heavy cast iron	2 18 0	to 3 0 0
Good machinery	3 2 6	to 3 5 0
Cleveland—		
Heavy steel	2 17 6	
Steel turnings	2 0 0	
Heavy cast iron	3 2 6	
Heavy machinery	3 5 0	
Midlands—		
Light cast-iron scrap	2 12 6	to 2 15 0
Heavy wrought iron	3 7 6	to 3 10 0
Steel turnings	2 2 6	
Scotland—		
Heavy steel	2 17 6	
Ordinary cast iron	3 6 6	to 3 7 6
Engineers' turnings	2 2 6	
Cast-iron borings	1 17 6	to 1 18 6
Wrot-iron piling	3 10 0	
Heavy machinery	3 11 0	to 3 11 3

London—Merchants' buying prices, delivered yard.

Copper (clean)	30 0 0
Brass	19 10 0
Lead (less usual draft)	13 10 0
Tea lead	9 0 0
Zinc	9 0 0
New aluminium cuttings	74 0 0
Braziery copper	27 0 0
Gunmetal	28 0 0
Hollow pewter	155 0 0
Shaped black pewter	116 0 0

PIG-IRON

N.E. Coast (d/d Tees-side area)—	
Foundry No. 1	72/6
,, No. 3	70/-
,, at Falkirk	70/-
,, at Glasgow	73/-
,, No. 4	69/-
Forge No. 4	69/-
Hematite No. 1	77/-
Hematite M/Nos.	76/6
N.W. Coast—	
Hem. M/Nos. d/d Glas.	77/-
,, d/d Birm.	88/6
Malleable iron d/d Birm.	120/-
Midlands (d/d Birmingham dist.)—	
Staffs No. 4 forge	72/-
,, No. 3 fdry.	75/-
Northants forge	69/6
,, fdry. No. 3	72/6
,, fdry. No. 1	75/6
Derbyshire forge	72/-
,, fdry. No. 3	75/-
,, fdry. No. 1	78/-
Scotland—	
Foundry, No. 1, f.o.t.	81/6
,, No. 3, f.o.t.	79/-
Hem. M/Nos. d/d	77/-
Sheffield (d/d district)—	
Derby forge	69/6
,, fdry. No. 3	72/6
Lincs forge	69/6
,, fdry. No. 3	72/6
W.C. hematite	90/-
Lancashire (d/d eq. Man.)—	
Derby fdry. No. 3	78/-
Staffs fdry. No. 3	78/-
Northants fdry. No. 3	76/6
Cleveland fdry. No. 3	78/-
Dalzell, No. 3 (special)	102/6 to 105/-
Glengarnock, No. 3	89/-
Clyde, No. 3	89/-
Monkland, No. 3	89/-
Summerlee, No. 3	89/-
Eglinton, No. 3	89/-
Gartsherrie, No. 3	89/-
Shotts, No. 3	89/-

FINISHED IRON AND STEEL

Usual district deliveries for iron; delivered consumer's station for steel.

Iron—	£ s. d.	£ s. d.
Bars (cr.)	10 2 6	
Nut and bolt iron	8 10 0	to 9 0 0
Hoops	11 0 0	and up.
Marked bars (Staffs) f.o.t.	12 10 0	
Gas strip	11 0 0	and up.
Bolts and nuts, ¾ in. × 4 in.	15 15 0	and up.
Steel—		
Plates, ship, etc.	8 15 0	to 8 17 6
Boiler plts.	9 5 0	to 9 7 6
Chequer plts.	10 7 6	
Angles	8 7 6	
Tees	9 7 6	
Joists	8 15 0	
Rounds and squares, 3 in. to 5½ in.	9 7 6	
Rounds under 3 in. to ⅜ in. (Untested)	9 1 0	
Flats—8 in. wide and over	8 12 6	
,, under 8 in. and over 5 in.	8 17 6	
Rails, heavy	8 5 0	to 8 10 0
Fishplates	12 10 0	
Hoops (Staffs)	9 16 0	
Black sheets, 24g. (4-t. lots)	11 10 0	
Galv. cor. shts. (,,)	13 10 0	
Galv. flat shts. (,,)	14 0 0	
Galv. fencing wire, 8g. plain	15 0 0	
Billets, soft	5 17 6	and up.
Billets, hard	6 17 6	to 7 2 6
Sheet bars	5 15 0	to 6 5 0
Tin bars	5 15 0	to 6 5 0

PHOSPHOR BRONZE

	Per lb. basis
Strip	10½d.
Sheet to 10 w.g.	11½d.
Wire	12½d.
Rods	11½d.
Tubes	14d.
Castings	12½d.

Delivery 3 cwt. free.
10% phos. cop. £30 above B.S.
15% phos. cop. £35 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. CLIFFORD & SON, LIMITED.

NICKEL SILVER, &c.

	Per lb.
Ingots for raising	7d. to 1/1
Rolled—	
To 9 in. wide	1/1 to 1/7
To 12 in. wide	1/1½ to 1/7½
To 15 in. wide	1/1½ to 1/7½
To 18 in. wide	1/2 to 1/8
To 21 in. wide	1/2½ to 1/8½
To 25 in. wide	1/3 to 1/9
Ingots for spoons and forks	7d. to 1/3½
Ingots rolled to spoon size	10d. to 1/6½
Wire round—	
to 10g.	1/4½ to 1/11½

with extras according to gauge.
Special 5ths quality turning rods in straight lengths, 1/3½ upwards.

AMERICAN IRON AND STEEL

At Pittsburgh unless otherwise stated.

	Dols.
No. 2 foundry, Phila.	21.31
No. 2 foundry, Valley	19.50
No. 2 foundry, Birm.	15.50
Basic, Valley	19.00
Malleable, Valley	19.50
Grey forge, Valley	19.00
Ferro-mang. 80%, seaboard	75.00
O.-h. rails, h'y, at mill	36.37½
Billets	28.00
Sheet bars	28.00
Wire rods	38.00
	Cents.
Iron bars, Chicago	1.80
Steel bars	1.85
Tank plates	1.80
Beams, etc.	1.80
Skelp, grooved steel	1.80
Steel hoops	2.10
Sheets, black, No. 24	2.40
Sheets, galv., No. 24	3.10
Wire nails	2.10
Plain wire	2.40
Barbed wire, galv.	2.60
Tinplates, 100-lb. box	$5.25

COKE (at ovens)

Welsh foundry	25/- to 32/6
,, furnace	20/- to 25/-
Durham foundry	25/- to 26/-
,, furnace	22/6
Scotland, foundry	30/-
,, furnace	25/- to 26/-

TINPLATES

f.o.b. Bristol Channel ports.

I.C. cokes	20×14 per box	18/9
,,	28×20 ,,	37/6
,,	20×10 ,,	27/-
,,	18¾×14 ,,	19/6
C.W.	20×14 ,,	15/9 to 16/3
,,	28×20 ,,	34/3
,,	20×10 ,,	23/-
,,	18¾×14 ,,	15/9 to 16/3

SWEDISH CHARCOAL IRON & STEEL

Pig-iron	£6 0 0 to £7 0 0
Bars-hammered, basis	£16 0 0 to £16 10 0
Bars and nail-rods, rolled, basis	£15 15 0 to £16 0 0
Blooms	£10 0 0 to £12 0 0
Keg steel	£30 0 0 to £31 0 0
Faggot steel	£18 0 0 to £23 0 0
Bars and rods dead soft, st'l	£10 0 0 to £12 0 0

All per English ton, f.o.b. Gothenburg.
[Subject to an exchange basis of Kr. 18.16 to £1.]

DAILY FLUCTUATIONS

Standard Copper (cash)

	£ s. d.	
May 14 ..	36 13 9 inc.	2/6
„ 15 ..	36 16 3 „	2/6
„ 18 ..	36 12 6 dec.	3/9
„ 19 ..	36 11 3 „	1/3
„ 20 ..	36 5 0 „	6/3

Electrolytic Copper

	£ s. d.	
May 14 ..	40 15 0 No change	
„ 15 ..	41 0 0 inc.	5/-
„ 18 ..	40 15 0 dec.	5/-
„ 19 ..	40 15 0 No change	
„ 20 ..	40 10 0 dec.	5/-

Standard Tin (cash)

	£ s. d.	
May 14 ..	204 10 0 inc.	15/-
„ 15 ..	205 7 6 „	17/6
„ 18 ..	202 15 0 dec.	52/6
„ 19 ..	200 5 0 „	50/-
„ 20 ..	198 5 0 „	40/-

Tin (English ingots)

	£ s. d.	
May 14 ..	204 15 0 inc.	15/-
„ 15 ..	205 10 0 „	15/-
„ 18 ..	203 0 0 dec.	50/-
„ 19 ..	200 5 0 „	55/-
„ 20 ..	198 5 0 „	40/-

Spelter (ordinary)

	£ s. d.	
May 14 ..	14 10 0 inc.	2/6
„ 15 ..	14 16 3 „	6/3
„ 18 ..	14 13 9 dec.	2/6
„ 19 ..	14 10 0 „	3/9
„ 20 ..	14 7 6 „	2/6

Spelter (Electro, 99.9 per cent.)

	£ s. d.	
May 14 ..	16 12 6 inc.	2/6
„ 15 ..	16 17 6 „	5/-
„ 18 ..	16 15 0 dec.	2/6
„ 19 ..	16 12 6 „	2/6
„ 20 ..	16 10 0 „	2/6

Lead (soft foreign, prompt)

	£ s. d.	
May 14 ..	15 8 9 inc.	3/9
„ 15 ..	15 10 0 „	1/3
„ 18 ..	15 10 0 No change	
„ 19 ..	15 10 0 „	„
„ 20 ..	15 7 6 dec.	2/6

Lead (English)

	£ s. d.	
May 14 ..	17 10 0 inc.	5/-
„ 15 ..	17 10 0 No change	
„ 18 ..	17 10 0 „	„
„ 19 ..	17 10 0 „	„
„ 20 ..	17 10 0 „	„

Imports and Exports of Pig-Iron and Steel Castings, etc., in April, and the Four Months 1936, compared with April, and the Four Months 1935.

	April.		Four Months.		April.		Four Months.	
	1935.	1936.	1935.	1936.	1935.	1936.	1935.	1936.
	Tons.	Tons.	Tons.	Tons.	£	£	£	£
Imports.								
Pig-iron—from British India	2,978	4,442	27,234	22,475	8,706	13,645	79,253	70,132
„ Foreign Countries	1,172	3,533	4,541	9,483	7,090	15,314	26,724	48,400
Total	4,150	7,975	31,775	31,958	15,796	28,959	105,977	118,532
Castings and forgings	433	793	1,078	2,993	9,474	25,754	28,161	97,079
Cast pipes and fittings	54	136	250	445	1,757	5,400	11,039	15,972
Stoves and grates, etc.	116	70	354	221	10,524	6,144	32,310	25,742
Baths	510	345	2,068	2,248	13,474	9,546	56,635	57,658
Hollow-ware, all kinds	249	295	818	1,089	16,585	19,085	52,827	62,763
Exports.								
Pig-iron, forge and foundry	11,382	3,921	29,702	16,715	39,549	14,867	102,397	61,991
„ acid	7,213	5,077	16,329	12,338	22,928	17,786	52,066	42,405
„ basic	1	55	204	105	5	361	604	545
Total	18,596	9,053	46,235	29,158	62,482	33,014	155,067	104,941
Castings and forgings	351	387	1,422	1,565	13,516	14,451	53,204	55,985
Cast pipes and fittings, up to 6 in. diameter	3,865	5,172	17,679	17,900	43,726	51,663	195,032	197,686
„ „ „ over 6 in.	2,938	3,188	12,849	14,964	22,010	25,359	101,179	120,663
Stoves, grates, etc.	554	735	2,568	3,455	30,624	37,718	129,726	174,281
Sanitary cisterns	174	272	1,023	1,022	5,369	7,960	28,551	32,215
Bedsteads, including tubes therefor	353	421	1,446	1,682	13,228	15,921	54,249	62,568
Cast hollow-ware	370	429	1,314	1,726	14,441	15,326	50,666	61,860

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(A remittance should accompany instructions.)

SITUATIONS VACANT AND WANTED

ASSISTANT Foundry Foreman wanted with experience in light steel castings, used to modern methods and some technical knowledge. An excellent opportunity with prospects for right man. Write giving age, experience, and salary required, to Box 708, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

EXPERIENCED Costs Clerk required to take charge of foundry costing system. Progressive position for right man. State age, full qualifications, and salary required.—Box 736, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

LEADING Moulder as deputy foreman in foundry in South, must have had good experience in general work. Give full particulars of experience, age, etc.—Box 730, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

MOULDERS wanted for heavy and light engineers' castings. Write stating age, experience, rate, and when available.—OXFORD & COWLEY IRONWORKS, LTD., Cowley, Oxford.

WANTED by London Foundry, experienced man to take charge of estimating department for iron castings. State experience.—Box 732, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

WORKING Chargehand required for a small foundry situated in South Midlands; good position for a capable man who can get results; must have experience in pneumatic and hand machines in addition to hand moulding in cast iron and non-ferrous metal. State age and wages to Box 718, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

EMPLOYMENT REGISTER.

Conducted by the Institute of British Foundrymen by courtesy of the proprietors of THE FOUNDRY TRADE JOURNAL.

Correspondence should be addressed to the General Secretary, Institute of British Foundrymen, St. John Street Chambers, Deansgate, Manchester, from whom full particulars can be obtained of this service.

Any employer wishing to communicate with a candidate should write to the General Secretary, quoting identification number.

POSITION required as Foundry Foreman. Marine engineering and general engineering experience of varied character. (277)

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